Innovative Synergy between Slope Upgrading and Ecological Conservation in Preventive Maintenance Programme

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ABSTRACT

In order to preserve the natural woodland and vegetation under Preventive Maintenance Programme of Highways Department of HKSAR (HyD), tree preservation and species conservation are of important factors to be considered during the construction phase. However, drawbacks such as degraded micro-habitats, diminished both bio- & genetic diversities from non-native sources, and the challenges of maintenance works against invasive plants persist. Traditional post-construction soft landscape plantation is often insufficient in addressing such complex ecological issues, especially in exposed / ecologically sensitive slopes. This paper shares a practical, collaborative case study between Ecologists / Plant Specialists and Geotechnical Engineers in preserving a natural floral community during slope upgrading works. Challenges and lessons learnt in this case contribute to an insight for sustainable management of both ecological preservation and slope engineering project.

1 INTRODUCTION

The Prevention Maintenance Programme of Highways Department of HKSAR (HyD) has evolved not only to stabilize substandard roadside man-made features from an engineering aspect; but also puts significant efforts to ensure that upgraded features are well blended with the surrounding natural environment as far as practical. Other than visual amenity, ecological considerations has been taken an increasing role in slope vegetation cover in recent years, especially in man-made features adjacent to ecologically sensitive areas (e.g. conservation areas/ Country Parks). Such ecological consideration aims at maintaining the original habitat or enhancing habitat quality and floral diversity as a resource for various local wildlife.

Feature No. 15NE-B/C273 located at Shek O Road was a selected roadside man-made slope feature to be upgraded under Prevention Maintenance Programme of HyD. The feature is an approximately 125m long soil and rock cut slope. The cut slope has a maximum height of 18m and an average slope angle of 45^{o}. The southern end and the crest of the middle portion of the feature was covered in vegetation (30%) while the rest of the feature was covered in shotcrete (70%). During the course of the slope upgrading works, Landscape Division of HyD expressed important concern on the high amenity value of the existing woodland at the southern end of the feature (Figure 1, Plates 1 and 2). The preservation includes the existing trees and species of conservation value and also the natural vegetation was of importance during construction phase.

This paper shares a practical, collaborative case study between Ecologists / Plant Specialists and Geotechnical Engineers in preserving a natural floral community during the planning stage and implementation stage of the slope upgrading works. Meanwhile, discussions on the challenges encountered and lessons learnt in this case provide insight for sustainable management of both ecological preservation and slope engineering.

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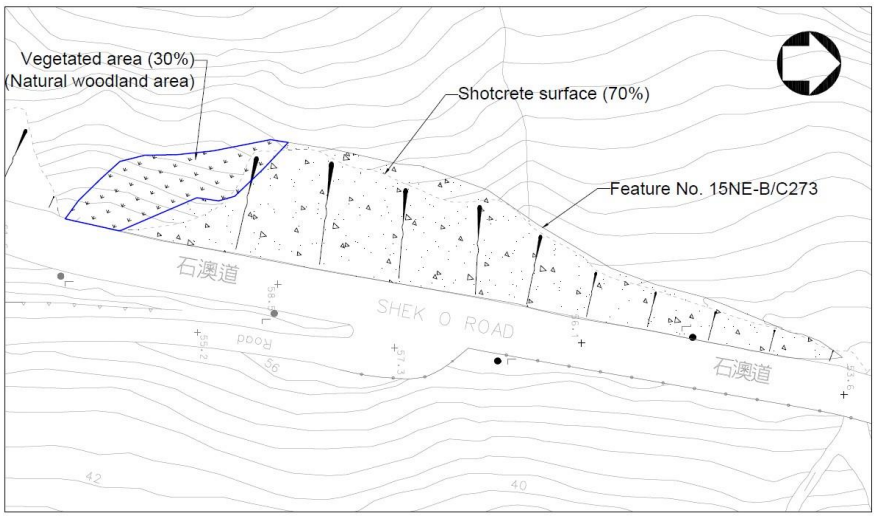

Figure 1: Location Plan of Concerned Natural Woodland Area at Feature No. 15NE-B/C273

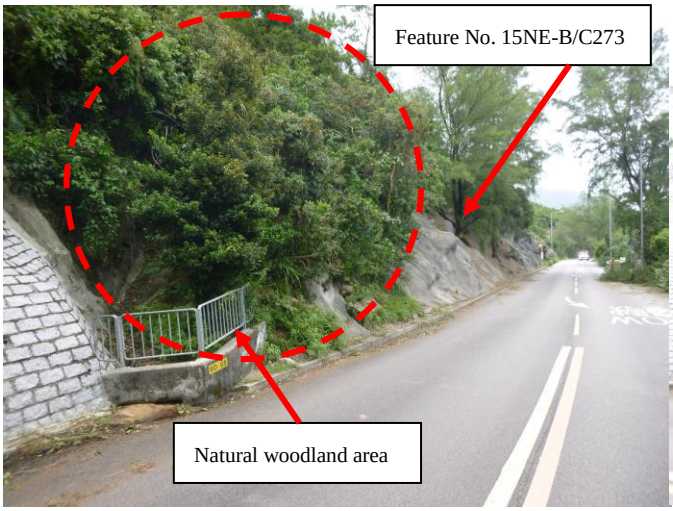

Plate 1: Existing condition of natural woodland area prior to commencement of works (View from South-eastern direction) (Date: 24/08/2017)

Plate 2: Existing condition of natural woodland area prior to commencement of works (View from Eastern direction) (Date: 24/08/2017)

2 SEQUENECE OF WORKS

2.1 Ecological Condition Survey

The Government has implemented a comprehensive range of administrative requirements for tree preservation such as the submission of Engineering and Landscape Plans, Tree Preservation and Removal Proposals (TPRP) and Arboricultural Assessment Reports (AAR) for all government project as stipulated in DEVB TC(W) No. 7/2015 (Development Bureau, 2015). On top of the above, an Ecological Condition Survey in woodland area (ECS) was suggested in Jan 2020 to obtain up-to-date baseline information on habitat type, vegetation communities, and presence of any species of conservation importance within the concerned woodland area (Plates 3 and 4). Information presented by a tree survey / tree risk assessment was not included in the scope of the ECS. An ecologist / Plant Specialist was assigned to identify target species of vegetation to be retained before site clearance works commenced at the Southern portion of the slope. A methodology of ECS was submitted to HyD for comment prior to the commencement of the physical survey. The field surveys covered not only flora but also animal groups. In case important feeding / breeding habitat and fauna species of conservation importance were revealed, corresponding mitigation measures should also be proposed. However, the ECS results found that there were no conservation concerns for fauna but only the floral community baseline with some plant species of conservation importance.

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Plate 3: Ecological Condition Survey in woodland area (ECS) conducted by Landscape Contractor and Ecologist / Plant Specialist with Geotechnical Engineer

Plate 4: Locating Species of Conservation Importance by Ecologist / Plant Specialist

The floral community consisted of various plants forming a complex structure of shaded woodland area (Table 1). Over 92% of the recorded species are native which are locally common in Hong Kong (Corlett et al., 2000; Hong Kong Herbarium, 2024) and would be very likely prone to site clearance during the construction phase. Three species of conservation importance were recorded within the survey extent (Figure 2).

Table 1: Plant Species Recorded during the Ecological Condition Survey in Natural Woodland Area (ECS)

Type	**Plant groups (Dominated species); Species of conservation importance***	**No. of species recorded**
Tree	• *Celtis timorensis* (假玉桂) • *Pinus massoniana* (馬尾松) • *Schefflera heptaphylla* (鴨腳木) • *Styrax suberifolius* (栓葉安息香)	14
Shrub	• *Carallia brachiata* (竹節樹) • *Gardenia jasminoides* (梔子) • *Litsea rotundifolia var. oblongifolia* (豺皮樟) • *Diospyros vaccinioides* (小果柿)* • *Pavetta hongkongensis* (香港大沙葉)*	18
Herbaceous plant	• *Liriope spicata* (山麥冬) • *Asparagus cochinchinensis* (天門冬)	5
Climber	• *Smilax* spp. (菝葜屬) • *Strychnos* sp. (馬錢屬) • *Gnetum luofuense* (羅浮買麻藤)*	15
	TOTAL	**52**

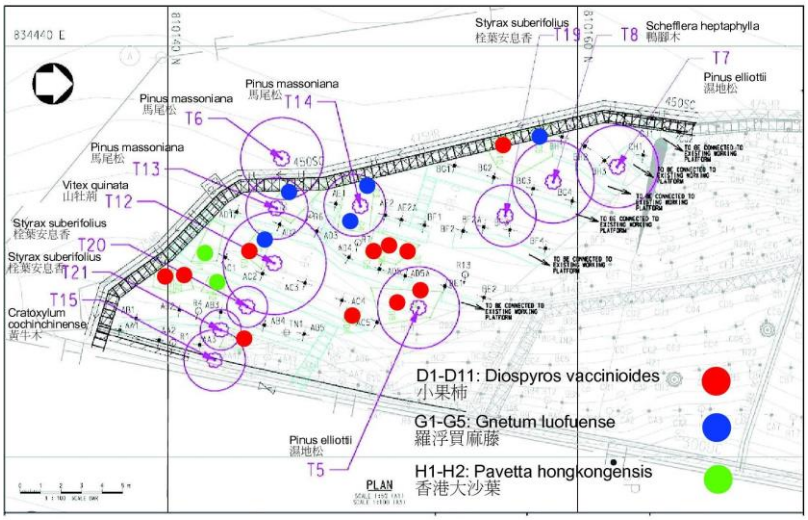

Figure 2: Recorded Trees and Plant Species of Conservation Importance with Corresponding Protection Zones

2.2 Design Revision to Preserve the Existing Vegetation

Noting there were dense vegetation growing on the natural slope on the southern end of slope with species of conservation importance, design amendment was required to preserve the existing vegetation as much as possible. The design revision was submitted for approval as detailed in Table 2 below.

Table 2: Summary of Design Revision to Preserve Vegetation

No.	Item	Revision	Beneficial Effects to Woodland Area
1.	Soil Nails	• The spacing of soil nails was changed from 1.5m centre-to-centre to 2.0m centre-to-centre in horizontal direction.	• To reduce the soil nail density in the woodland area so that total extent of excavation of soil nail head could be reduced in the woodland area.
		• Diameter of 10 nos. of soil nails had been increased from 100mm to 150mm; and the spacing of 3 nos. soil nails at the crest of the woodland area has been changed from 1.5m to 1.3m.	• To compensate of reduction of soil nail density in order to meet the design requirement of slope stability.
2.	Surface Protection	• Biodegradable erosion control mat of natural jute fibre type with minimum average weight 500 g/m^2 was applied.	• To preserve and retain the existing species within the woodland area, as the application of non-biodegradable erosion control mat with hydroseeding may hinder the growth of existing species to be retained.
3.	Surface Drainage System and Maintenance Access	• A new alignment of the stepped channel was counter-proposed as the position of the original proposed 300mm U-channel with concrete apron and 300mm high upstand is in conflict with the vegetation growing on the natural slope.	• To minimize the impact on the woodland area so that natural rainwater will not be completely diverted away from the vegetation and to lessen the visual impact of the stepped channel leading to the slope toe.
		• The portion of 300mm U-channel with concrete apron in the vegetated slope portion was deleted accordingly. A 300mm diameter downpipe was proposed to convey the surface runoff rather than a stepped channel.	• To suit the actual site conditions and reduce the extent of excavation and concrete works on the slope surface in woodland area (Plates 5 and 6).
		• The alignment of the steel maintenance staircase was further adjusted to the centre of the slope and the mid-berm access with U-channel were deleted within natural woodland area.	• To preserve trees and natural slope vegetations as much as possible (Figures 3 and 4).

Plate 5: A new stepped channel alignment was counter-proposed to preserve the flora species of conservation importance fenced off by an orange net

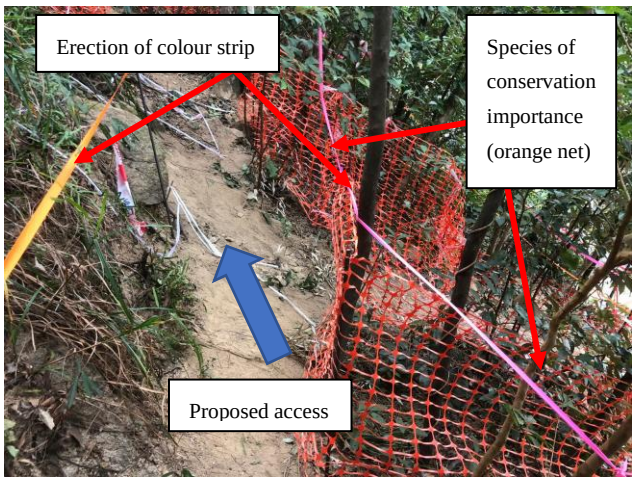

Plate 6: Condition of natural woodland area when assigning erection of access

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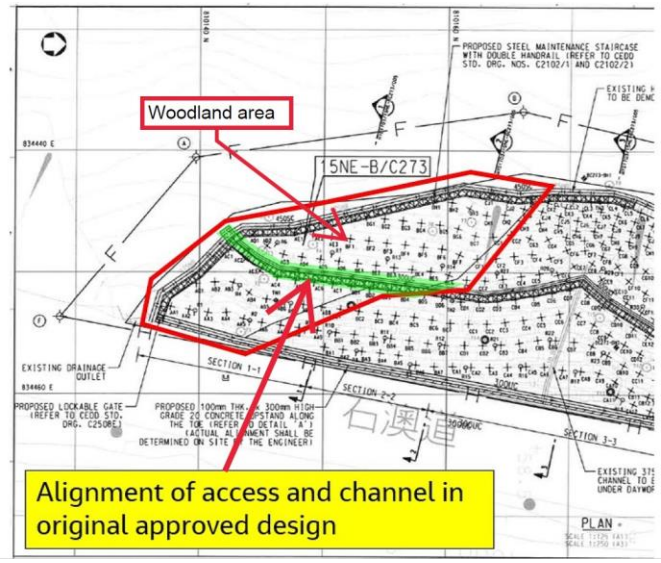

Figure 3: Alignment of access and channel in Original Approved Design

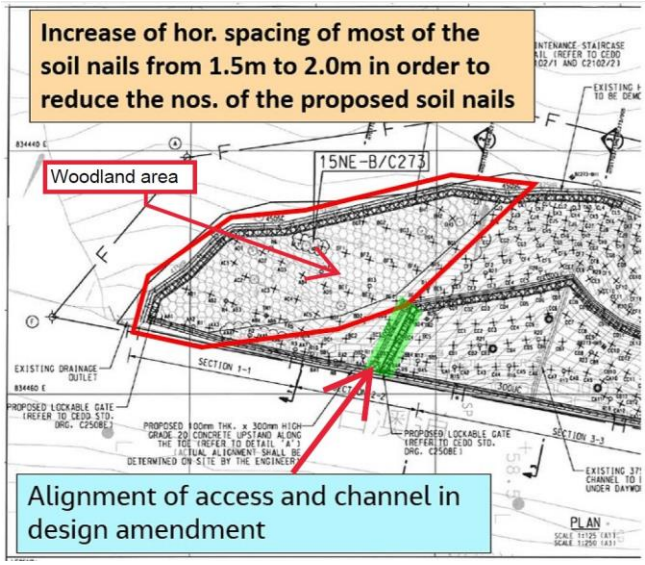

Figure 4: Alignment of access and channel in Design Revision

2.3 Erection of Temporary Access and Protection Measures

After conducting the ECS, the draft works alignment was marked temporarily using the colour strips by fitting the mosaics of dense vegetation. All existing trees, species of conservation importance and woody vegetation were appropriately cordoned off by orange net (Plates 7 and 8). For secure protection, all the area outside the colour strips of lands reserved for soil nail head / temporary access and working platform were also cordoned off properly (Plate 7). Photo records upon completion of fencing was submitted to HyD for obtaining their consent for erection of physical temporary access and working platform.

Having experienced the practicability of erecting the temporary access and working platform for equipment mobilization and construction activities at the first two uppermost rows of soil nails, further on-site adjustment was made for the remaining rows of soil nails as required when deemed necessary.

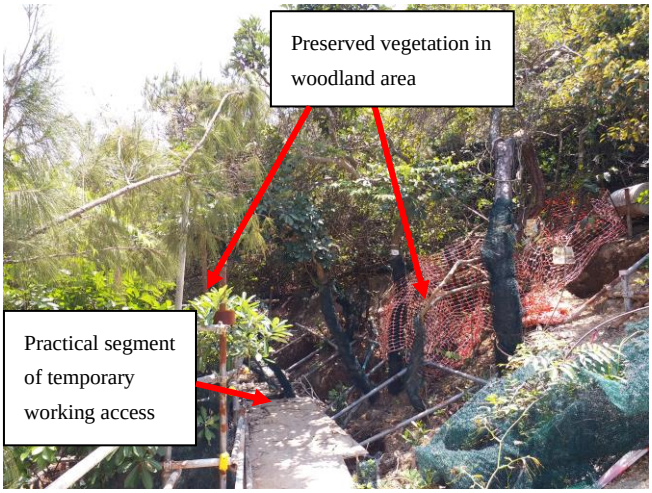

Plate 7: A practical segment of temporary working access among preserved vegetation

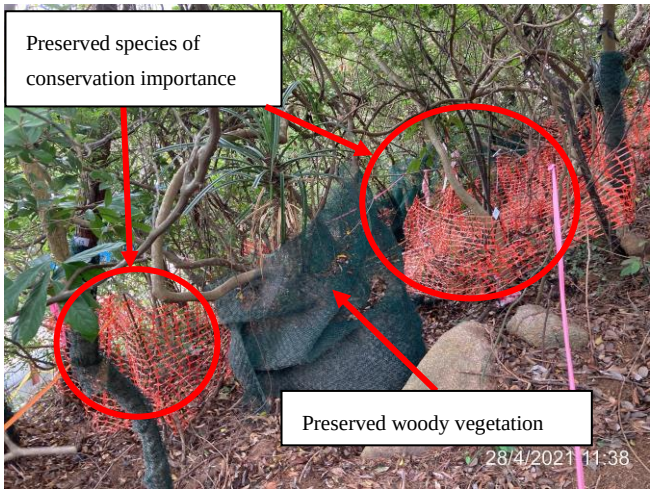

Plate 8: Woody vegetation was preserved by a green fence while orange fence was used for species of conservation importance. Preserved woody climber provided a shaded canopy layer to sustain the microhabitat.

2.4 Limited Site Clearance with Selective Trimming of Vegetation

To minimize disturbance to the natural woodland area, site clearance was minimal and restricted to areas only for erection of temporary access and working platforms under the supervision of the Landscape Contractor with landscape softworks or establishment works experience and Ecologist / Plant Specialist. To further minimize the impact from the engineering works, a specialist team was engaged to conduct site clearance and vegetation preservation works.

When a localized clearance was unavoidably, the selective trimming of woody plants would be carried out under the supervision of the Ecologist / Plant Specialist and the Geotechnical Engineer. Non-woody herbaceous plants and grass was not limited for site clearance. If the common plant species without conservation importance was affecting the erection of the working platform, the authorized Landscape Contractor (but not other site workers) conducted the selective trimming (Plates 9 to 12) and pruning of the hanger and overhanging branches affecting headroom as identified on site during inspection also had to be carried out.

Plate 9: Before selective trimming during erection of scaffolding and working platform for soil nail Row BH in woodland area

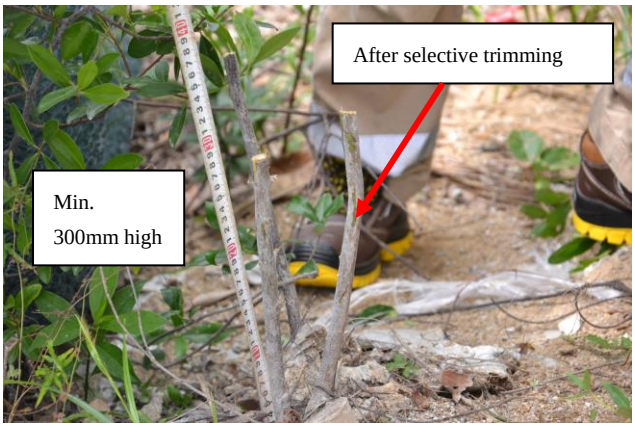

Plate 10: After selective trimming, erection of working platform will avoid soil compaction and risk of stepping on the remaining stems by the workers

Plate 11: Only hand-held tools were allowed for selective trimming. Plant identification and extent of trimming was confirmed by the Ecologist before trimming.

Plate 12: Adventitious root system of *Pandanus* sp. (露兜樹屬) allows a quicker recovery against selective trimming of its spiky leaves that obscuring the work path. The clutch was preserved as a good coverage at the boulder zone.

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2.5 Inspection Pits Excavation with Relocation of Soil Nails

The aim of an Arboricultural Assessment Report (AAR) is to assess the impact of the proposed construction work through inspection pit excavation in the proposed soil nail location and to review the method statement of the engineering and tree protection works including the Methodology of Soil Nailing Works in Woodland Area. Inspection pit excavation in the proposed soil nail location (i.e. 400mm x 400mm x 250mm) was carried out prior to installation of soil nails to ascertain whether the proposed soil nailing work including installation of soil nail head (i.e. 600mm x 600mm x 250mm) would be in conflict with the tree roots and make adjustment as appropriate to avoid the conflict and recorded in the AAR.

A Certified Arborist of the International Society of Arboriculture (ISA) was assigned to supervise and inspect the inspection pit excavation on-site in order to prevent major tree roots damage during excavation. Manual excavation of inspection pit at each soil nail location within a tree protection zone (TPZ) was adopted to confirm any tree roots at the proposed soil nail location (Plates 13 and 14). If significant tree roots were encountered in the inspection pit, the soil nail had to be re-adjusted to minimize adverse impact to the existing trees (Plates 15 and 16). No major tree roots were observed in the excavated inspection pits for this site. Photographic records of each of the inspection pit were provided and the amount of root loss was recorded. The exact location of the adjusted soil nail head was confirmed on-site and recorded in the revised working drawings.

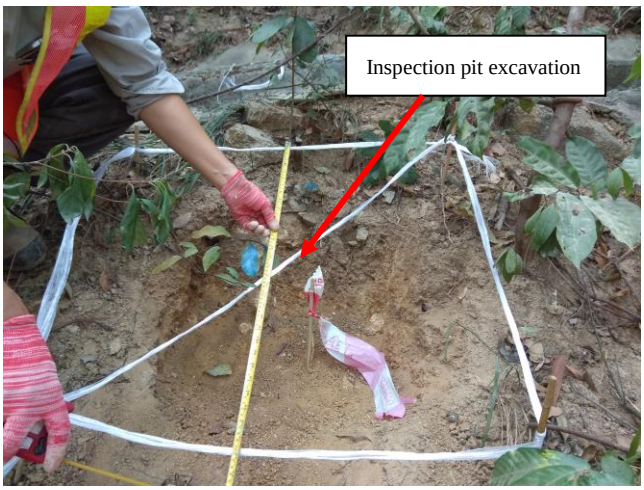

Plate 13: Inspection pit excavation for Row BG Soil Nails

Plate 14: Inspection pit excavation for Row BF Soil Nails

Plate 15: Original soil nail head locations at Row BG

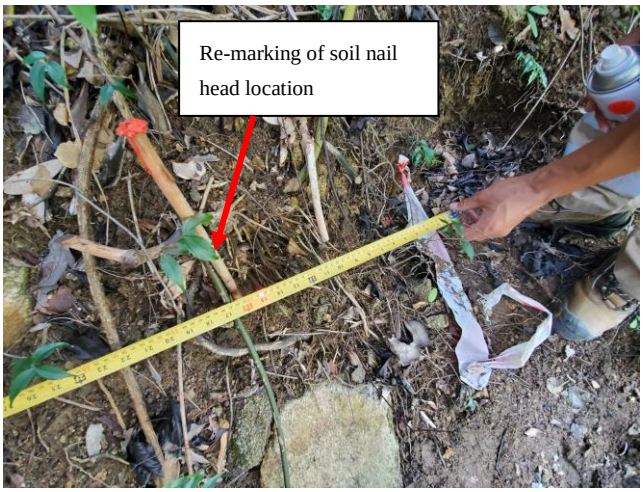

Plate 16: Re-marking of soil nail head locations at Row BG

2.6 Erection of Temporary Scaffolding and Working Platform for Soil Nailing Works

Erection of temporary scaffolding and working platforms was considered unavoidable for soil nailing works. 600mm wide temporary access and 1m wide working platform were originally proposed. It was considered that the tiebacks / metal poles of stabilizing the scaffolding of temporary access and working platform outside the soil nail head ("SNH") area had to be minimized to reduce the damage to the preserved vegetation. Hence, 900mm wide temporary access and working platform was counter-proposed to allow the workers to carry out the soil nailing works which is considered the optimized platform design with the least number of tiebacks / metal poles outside the 800mm x 800mm SNH area (Figures 5A and 5B). In the meantime, sufficient temporary working space could be provided to safeguard the workers safety.

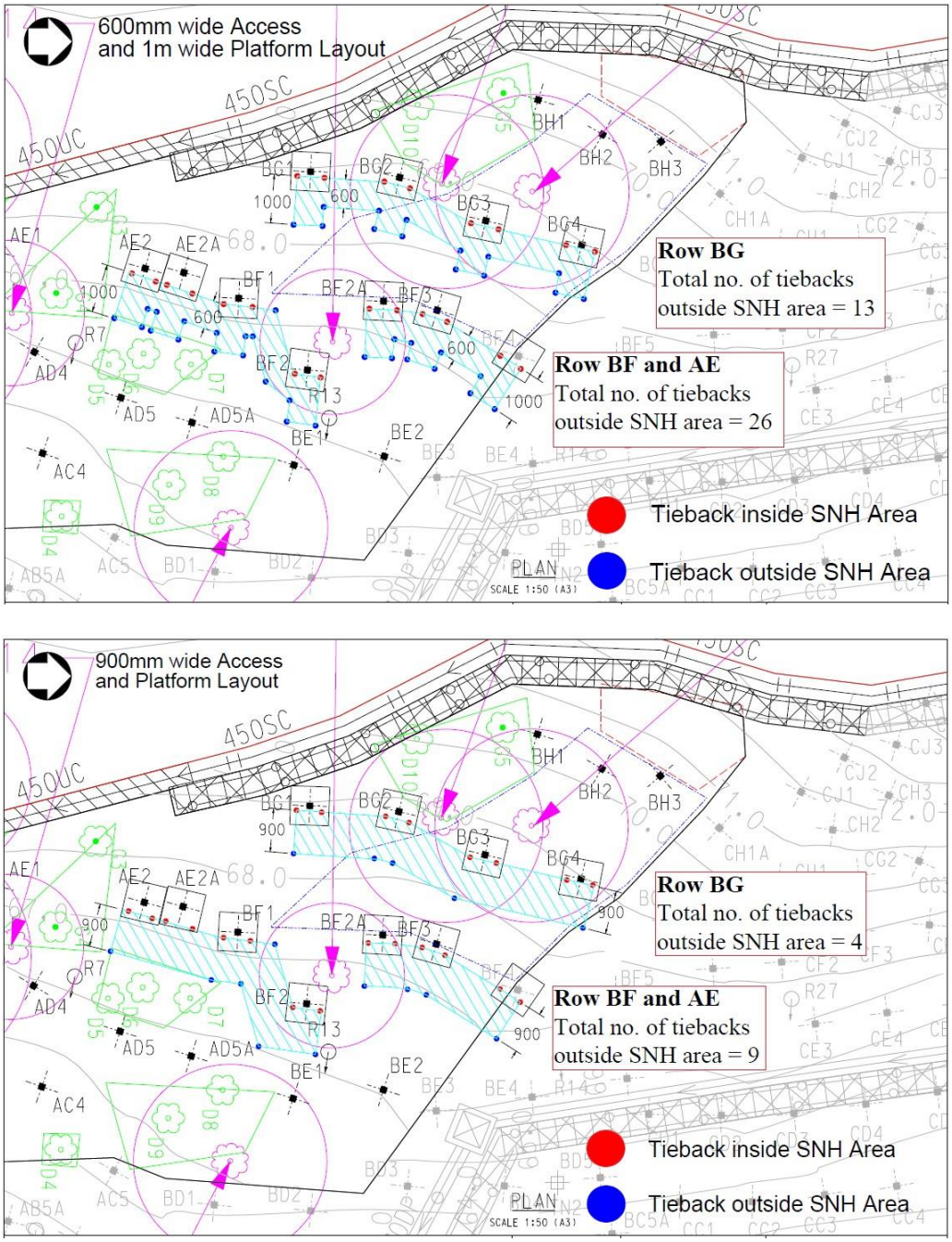

Figure 5A (upper) and Figure 5B (lower): Fewer tie backs were needed for soil nailing works at Row BG, BF and AE when the width of the access and working platform layout changed from 600mm and 1m respectively into 900mm

2.7 Soil Nailing Works in Woodland Area

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A "method statement for soil nailing works in woodland area" ("MS") appending the sequence of works had to be submitted for approval prior to commencement of soil nailing works within the woodland area. According to the MS, shorter steel bar combination was adopted for easier transportation among preserved vegetation. A steel effluent collecting tray was tailor-made by the Contractor and placed in the excavated soil nail head for water collection during the coring works (Plate 17). Adequate sand bags were also provided at the bottom of the tray as contingency measure. Effluent was then pumped to a sedimentation tank located outside the existing woodland. The route for effluent diversion was shown in the method statement for approval. Based on the experience of grouting for first two rows soil nails in woodland area, it was observed that longer construction time was required as only two nos. of effluent collecting trays could be placed for better control. After that, the Contractor proposed an alternative effluent collecting tray by using cement sand mortar and plastic sheet (Plate 18). This alternative tray not only could be placed in greater numbers within the woodland area for shortening the construction time, but also provided a good collection of effluent during coring works.

Plate 17: Tailor made effluent collecting tray using steel plate

Plate 18: Alternative effluent collecting tray using cement sand mortar and plastic sheet

2.8 Monthly Ecological Monitoring

Overall condition of preserved trees, species of conservation importance and woody vegetation; as well as the implementation of mitigation measures of plant preservation were monitored monthly by the Ecologist / Plant Specialist throughout the 32-month construction phase (January 2020 to August 2022) (Plates 19 to 28).

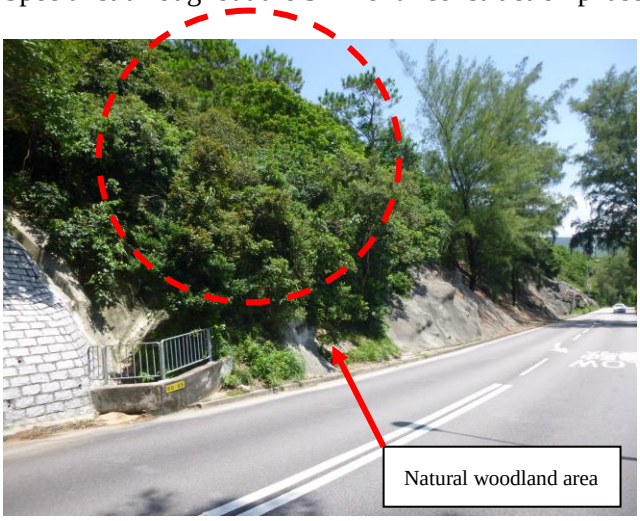

Plate 19: The woodland patch before slope upgrading works (Date: 26/07/2017)

Plate 20: The woodland patch after ECS before site clearance at dry season (Date: 16/01/2021)

Plate 21: The woodland patch three months after ECS (Date: 28/04/2021)

Plate 22: The woodland patch six months after ECS (Date: 29/07/2021)

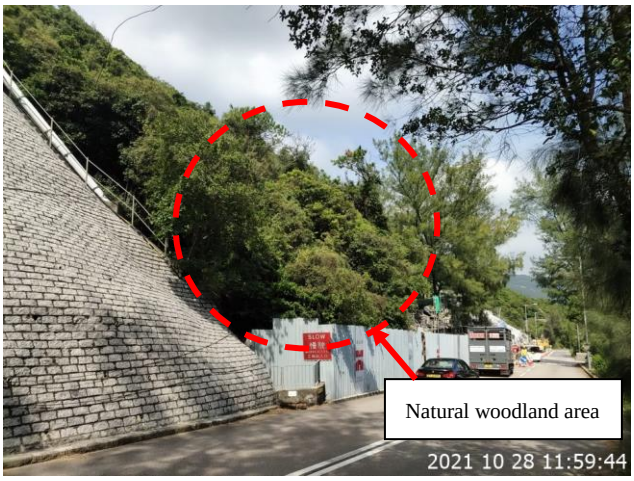

Plate 23: The woodland patch nine months after ECS (Date: 28/10/2021)

Plate 24: The woodland patch twelve months after ECS (Date: 11/01/2022)

Plate 25: The woodland patch fifteen months after ECS (Date: 30/04/2022)

Plate 26: The woodland patch eighteen months after ECS (Date: 26/07/2022)

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Plate 27: Preserved woodland patch after completion of construction phase in late wet season. (Date: 29/09/2022) Note that native parasitic climber *Cuscuta chinensis* (菟絲子) has been depressed by the recovering floral community. No invasive plants compete in a rather intact community of native species in various forms.

Plate 28: General view of preserved woodland patch 1 year after completion of construction phase. (Date: 19/08/2023)

3 CHALLENGES AND LESSONS LEARNT

This task provided the dynamic communications among Ecologists / Plant Specialists, Geotechnical Engineers and Contractors (construction and soft landscape) throughout the whole construction phase; rather than a top-down construction based on approved survey reports, design drawings and typical common practices.

3.1 Plant Preservation Priority

The biggest challenge was to provide works space for engineering structures in a dense woodland, which had no guarantee on its condition with such an intense works disturbance. The ECS aimed at advising what type of vegetation or plant species can be cleared, at what extent; such that core floral community could sustain a recovery to the same habitat type in a reasonable timeframe (i.e. woodland would not degrade into exposed shrubland or grassland during / after construction phase). From this case, the lesson learnt was that on top of species of conservation importance and existing trees that have to be preserved, protection priority would be given for the undersized trees (Diameter at breast height (DBH) < 95mm), tall shrubs, then woody climbers and lastly herbaceous plants. Among each plant forms, uncommon / species with restricted distribution but yet without any conservation status would be preserved with a higher priority. This requires highly experienced and qualified Ecologists / Plant Specialists with a sense of habitat quality and ecological value from site to site.

3.2 Drawbacks of Traditional Post-construction Soft Landscaping Works

Another challenge was that the drawbacks of traditional post-construction soft landscape plantation in terms of degraded micro-habitats, diminished bio- and genetic diversity from non-native nursery stocks, and challenges of maintenance works against invasive plants can be improved through a works design preserving the native vegetation. Whole natural floral community or diversity is hard to replicate, as reflected by 52 species observed in just 300m^2 of the works site. Post-construction soft landscape planting on slope feature seldom adopted more than 15 native species due to site constraints. This means there is always a degradation of the original habitat quality (at least at micro-habitat level) after slope upgrading works even if the survival rate of soft landscaping is assumed as 100%. In this case, Landscape Contractor has put greater efforts in protecting and selective trimming existing vegetation but a minimal soft landscaping only at highly eroded areas and around soil nail heads.

Given relatively high costs for land and the labour force in the local industry, Landscape Contractors often import from a few nursery stocks of commonly used native species with better survival and at lower cost, resulting in a non-native sources and diminished genetic diversity in plants used for soft landscape planting. However, a temporary holding nursery can be set up when works area is available for various woody shrubs and saplings before they could be transplanted back to the site construction activities. This encourages the Landscape Contractor to locally stock native plants that are still uncommonly available on the market.

3.3 Green Slopes without Invasive Plant Species

The last challenge is that construction sites are always vulnerable to invasive species, which further suppresses the recovery or even outcompetes soft landscape plantation on man-made slopes. As a result, maintenance work becomes a burden of challenge, a waste of planting efforts, poor recolonization of native floral community, and always ends up with a 'green' slope surface dominated by weeds and invasive species. A self-sustained native vegetation encourages recolonization of other natural plants if surrounding areas are in high ecological value; while it depresses the invasion of invasive species and weeds (e.g. *Bidens alba* (白花鬼針草), *Lantana camara* (馬纓丹), *Leucaena leucocephala* (銀合歡), *Mikania micrantha* (薇甘菊) and *Melinis repens* (紅毛草) for the case in Hong Kong) when adjacent areas has been disturbed or low habitat quality. Selective trimming of smaller woody plants preserved an intact root system to facilitate regeneration. These plants, despite being small in size, may already be of a mature stage compared to newly planted shrubs and groundcover. New root systems of soft landscape planting could be hard to establish in a harsh environment on slope features. In contrast, an intact root system of original vegetation maintains a suitable microhabitat, organic matters (top soil) and microbial communities for resilience of the protected plant species of conservation importance; and a better resistance to invasive species.

4 CONCLUSION

To summarize, a new ecological approach to minimize and mitigate impacts of slope upgrading works in woodland / natural habitat has been demonstrated by this task. Although working in a segmented working platform with a minimum working space among dense vegetation and canopy would result in a higher cost and longer work programme; such well-preserved habitat quality would enhance a minimal and more adaptive soft landscape planting. The higher habitat preservation cost at the beginning helps to lower maintenance effort and cost in long-term without degrading the habitat quality / ecological value of the upgraded slope. A reallocation of budget and construction programme should be considered when such practice will be adopted for natural terrain, or man-made slopes located within / in close vicinity of Conservation Areas / Sites of Special Scientific Interest (SSSI) / Country Parks.

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