Effects of construction waste on the growth of Potted Chinese Rose

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Abstract: In order to verify the feasibility of reclamation and utilization of construction wastes of different particle sizes in landscaping, construction wastes were screened out with 4 grain grades of 0-2mm, 2-3mm, 3-5mm and 0-6mm. According to the compound mass ratio of 10%, 20%, 30%, 40%, 50% and the soil, the effects of different particle size and proportion matrix treatment on soil bulk density and potted rose growth were studied. The results show that the bulk density of substrates decreases with the increase of the particle size and proportion of construction waste. In addition to no significant effect on leaf morphology, adding proper amount of construction waste to the soil had a significant effect on plant height, stem diameter increment, root length, root fresh weight, total flower number, chlorophyll content and nitrogen, phosphorus, potassium content in the plant of potted rose. However, excessive application of construction waste inhibited the growth of potted rose. In the comprehensive analysis, the optimal particle size was 3-5mm, followed by 2-3mm. The optimal proportion is 40%, followed by 30%. It is feasible to add construction waste as a modifier to landscaping matrix.

1. Introduction

With the acceleration of urbanization in China, a large amount of construction waste is generated during the demolition of old buildings and the construction of new buildings. For a long time, China has adopted the methods of open-air stacking and direct landfill to deal with construction waste, which has brought a series of ecological and environmental problems [1]. The generation and stacking of a large number of construction wastes not only causes significant pollution to the environment, but also aggravates the shortage of land and construction resources in China, which has become a "chronic disease" of urban development and urban management [2]. Only resource utilization can fundamentally solve the urban environmental problems caused by disorderly stacking and landfill of construction waste. At present, the utilization rate of construction waste in China is less than 5% [3], and the recycling of construction waste has attracted wide attention [4].

The most common way to recycle construction waste is to use concrete and mineral debris as filling materials for the construction of roads, embankments, ramps, etc. [5], but there is still a lack of discussion and research on landscaping and soil improvement. The soil in Shanghai gardens has some defects, such as alkaline pH, viscous texture, heavy volume and low organic matter content, which have been restricting the development of landscaping in Shanghai [6]. Rosa Hybrida L. is a kind of rose in the Family Rosaceae, a kind of traditional Chinese famous flower, of which there are a lot of varieties, including beautiful flower type and rich colors. Potted Chinese rose is an important cultivation method. Chinese rose prefers a warm, humid and sunny, well-ventilated environment. It is resistant to dampness and cold. Soil requires loose and fertile soil with good drainage and water retention [7]. In this study, the
The pot method was adopted to take construction waste as a soil improver and add it into the soil according to different particle sizes and proportions. The effects of different particle size and proportion of construction waste on the growth of potted rose were studied. The feasibility of the construction waste as a landscaping matrix and cohesive soil modifier was verified, and the most suitable particle size and proportion were screened out to explore a new way for the utilization of construction waste resources.

2. Materials and methods

2.1. Test materials
The experiment was conducted in the greenhouse of Fengxian Campus of School of Ecological Technology and Engineering, Shanghai Institute of Technology from April to December 2019. The soil was collected from the campus botanical garden, dried and ground naturally, sifted by 2mm, and mixed for use. The tested rose variety is "Queen of Sweden", provided by Changshu Jingnong Horticultural Technology Co., LTD. The construction waste used in the test came from the abandoned buildings demolished in Shanghai. After sorting and crushing by professional recycling companies, four kinds of grain sizes, 0-2mm, 2-3mm, 3-5mm and 0-6mm, were screened out. The basic properties of the tested soil and different grain sizes of construction wastes are shown in Table 1.

| Chemical properties | Test soil | Construction waste of different sizes |
|---------------------|-----------|-------------------------------------|
|                     | 0-2mm     | 2-3mm     | 3-5mm     | 0-6mm     |
| Organic matter/(g·kg⁻¹) | 15.62     | 15.33     | 12.43     | 7.38      | 10.18     |
| Total nitrogen/(g·kg⁻¹) | 0.41      | 0.12      | 0.19      | 0.22      | 0.09      |
| Total phosphorus/(g·kg⁻¹) | 0.54      | 0.37      | 0.38      | 0.41      | 0.43      |
| Total potassium/(g·kg⁻¹) | 15.37     | 4.36      | 5.04      | 4.63      | 4.80      |
| Alkali hydrolyzed nitrogen/(mg·kg⁻¹) | 12.13     | 14.88     | 24.74     | 35.74     | 11.14     |
| Available phosphorus/(mg·kg⁻¹) | 21.08     | 51.89     | 17.41     | 26.95     | 25.11     |
| Quick-acting potassium/(mg·kg⁻¹) | 171.33    | 572.67    | 402.00    | 346.67    | 437.00    |
| pH value             | 8.14      | 7.45      | 7.52      | 7.46      | 7.39      |

2.2. Experimental method
The construction waste is screened into 0-2mm, 2-3mm, 3-5mm, 0-6mm, 4 kinds of grain grades. According to the compound mass ratio of 10%, 20%, 30%, 40% and 50% and the soil, the construction wastes of different grain sizes were uniformly mixed into 20 groups of substrate treatments of different proportions, and one soil was used as CK control test substrate. There were 21 different treatments with 3 replicates per treatment, a total of 63 POTS, and the total weight of each pot substrate was 2kg. For each treatment of the test, water 100ml once a day, and simulate the natural settlement and contraction of the soil after watering. At the end of the watering period, the soil bulk density and porosity were measured by ring-knife sampling. After the measurement of bulk density and porosity, the plants with basically the same growth potential were selected. After the unified pruning, the plants were transplanted into red plastic flowerpots, and one plant was planted in each pot. Regular watering, weeding and pest control were carried out during the test. Plant growth was observed every 15 days with a complete growth cycle [8].

2.3. Project measurement

2.3.1. The physical properties of the matrix.
Bulk density was determined by ring knife method. Porosity = (1 - soil bulk density/soil density) ×100%[9].
2.3.2. Determination of morphological indexes.
It includes plant height, stem diameter increment, root length, root fresh weight, leaf length, leaf width, total number of flowers. The plant height, root length, and leaf length and width were measured with ruler before and after harvesting, respectively; the stem diameter was measured with vernier caliper before and after harvesting, and the increment was calculated. The total flower number was observed and recorded daily after planting, and the cumulative value was obtained. [10].

2.3.3. Determination of physiological indexes.
Three upper mature functional leaves were selected from each plant, and the chlorophyll content was determined by ethanol grinding method. The dry samples of the plants were determined by H2SO4-H2O2 ablation method for total nitrogen, molybdenum-antimony antiabsorbance spectrophotometry for total phosphorus, and flame photometry for total potassium [15].

2.3.4. Comprehensive scoring method.
The overall growth status of Chinese rose was evaluated by comprehensive scoring method. The subordinate function values of morphological indexes under different substrate ratios were obtained: \( X(\mu) = (X - X_{min}) / (X_{max} - X_{min}) \). Where \( X \) is the measured value of the index (\( \mu \)); \( X_{max} \) \( (X_{min}) \) is the maximum (minimum) value of the index. The subordinate function values of different morphological indexes under each substrate condition were accumulated and the average value was obtained. The higher the value, the better the plant growth under the substrate cultivation treatment [12].

2.3.5. Data analysis.
Use Excel2013 to organize data; SPSS 25.0 was used for analysis of variance and significance test. Original 2017 drawing.

3. Results and analysis

3.1. Effects of different substrate treatments on soil physical properties
The effects of treatment with different substrates on soil bulk density and porosity are shown in Table 2. The addition of construction waste can effectively reduce soil bulk density, and soil bulk density treated with different particle sizes all decreases with the increase of proportion. The bulk density measurement results of each treatment are shown in Figure 1. It can be seen from the figure that soil bulk density decreases after construction waste is added, among which 50% 0-2mm, 40% 0-3mm, 50% 0-3mm, and 0-6mm, 2-3mm, and 3-5mm are significantly different between the whole group and the control group (\( P < 0.01 \)).

In the 4 groups, the bulk density of 0-2mm, 0-6mm, 2-3mm and 3-5mm decreased by 2.51%, 5.18%, 3.65% and 7.06%, respectively, compared with the control group when treated with 10% in each group. Compared with CK, the bulk density of each group decreased by 4.12%, 8.97%, 8.44% and 15.65% respectively when treated with 50% of each group. It can be seen that the drop in bulk density of each group is arranged from small to large in percentage, and the drop in each group is the largest at 50% compared with CK.

Compared with CK group, the decrease of soil bulk density in 0-2mm group was the least, and that in 3-5mm group was the largest. Among all treatments, the soil bulk density of 6 treatments (50% 0-6mm, 50% 2-3mm, 20%, 30%, 40%, 50% 3-5mm) was less than 1.30g.cm-3, which met the important requirements of soil capacity for lawn, roadside trees and arbors in the "quality standard of planting soil for landscaping" compiled by Shanghai Landscape administration[13]. 30% 3-5mm, 40% 3-5mm and 50% 3-5mm met the requirements of soil bulk density ≤1.25g · cm-3 for flower border and shrub planting. The 50% 3-5mm treatment can meet the requirement of soil bulk density ≤ 1.20g.cm-3.

Compared with CK, soil porosity in each treatment after the addition of construction waste increased. With the increase of construction waste proportion, soil porosity showed an increasing trend, and with the increase of construction waste particle size, soil porosity also increased. It can be seen from the table
that construction waste in groups 2-3mm, 0-6mm and 3-5mm has the most significant improvement effect on porosity. With the increase of regenerated particle content, the porosity of each treatment showed a linear increasing trend.

### Table 2. Bulk density and porosity of soil treated with different substrates

| The granularity of construction waste | Bulk density (g•cm⁻³) | Usage amount | Porosity/% |
|--------------------------------------|-----------------------|--------------|------------|
|                                      | 10% 20% 30% 40% 50%   | 10% 20% 30% 40% 50% |
| 0-2mm                                | 1.39a 1.38a 1.38a 1.37a 1.35b | 49.64a 49.53a 49.55a 49.59a 50.00b |
| 2-3mm                                | 1.36ab 1.35ab 1.34ab 1.30bc 1.26c | 50.42c 50.46c 50.71c 55.25b 54.67a |
| 3-5mm                                | 1.30a 1.28ab 1.24bc 1.21cd 1.18d | 50.45b 51.59b 53.90a 53.91a 54.36a |
| 0-6mm                                | 1.38ab 1.36abc 1.33abc 1.30bc 1.28c | 51.00a 48.63a |

Note: Different letters indicate significant differences in processing (P<0.05), the same below.

### 3.2. Effects of different substrate treatments on plant morphological indexes of potted Chinese Rose

As shown in Table 3, after the addition of construction waste particles, the plant height and stem diameter increment of potted rose between treatments reached the significant standard (P<0.05). The change of leaf plant height and stem diameter increment in each group was increased with the increase of the proportion of construction waste particles, which showed a trend of first increasing and then decreasing. The plant height and ground diameter increment also reached the peak at 40%3-5mm, higher than CK 47.75% and 152.87%, respectively. With the increase of the proportion of construction waste particles, both root length and root fresh weight showed a trend of first increasing and then decreasing, which was greatly increased compared with CK. The peak value was 40%3-5mm, which was higher than CK 116.49% and 115.96% respectively. After the addition of construction waste particles, there was no significant difference between the leaf length and leaf width of each potted rose and CK. The results showed that the addition of construction waste to the soil played a role in promoting plant height, stem diameter and root growth of rose, but had no significant effect on leaf morphology (leaf length and leaf width). The total number of flowers was basically at a low level. Only 40% of the total flowers treated with 3-5mm had an average of more than 1 flower. However, compared with CK, all groups had hair spray.

### Table 3. Effects of different substrate treatments on morphological indexes of potted rose

| The granularity of construction waste | Usage amount | Plant height /cm | Stem diameter increment /mm | Root length /cm | Root fresh weight /g | Leaf length /cm | Leaf width /cm | Total flowers |
|--------------------------------------|--------------|------------------|-----------------------------|----------------|----------------------|----------------|---------------|--------------|
| CK                                   | 0 22.20d 2.90d 9.70d 6.52c 2.07b 1.62b 0.0a |
| 0-2mm                                | 10% 22.80bc 2.83bc 15.33c 9.17b 2.16ab 1.82a 0.0a |
|                                       | 20% 23.63bc 5.33ab 16.33bc 11.10ab 2.15ab 1.83a 0.0a |
|                                       | 30% 27.73a 6.73a 17.00ab 13.54a 2.19ab 1.87a 0.3a |
|                                       | 40% 28.57a 6.67a 17.70a 11.27ab 2.27a 1.95a 0.3a |
|                                       | 50% 25.13b 5.63ab 16.20bc 6.21c 2.18ab 1.83a 0.0a |
| 2-3mm                                | 10% 23.73cd 5.03c 16.33c 10.84b 2.23ab 1.80a 0.0a |
|                                       | 20% 26.27b 6.10b 17.60bc 11.61b 2.25ab 1.73a 0.3a |
|                                       | 30% 27.70ab 7.00a 18.50ab 12.65bc 2.30a 1.75a 0.7a |
|                                       | 40% 30.00a 7.57a 20.27a 14.42a 2.36a 1.80a 1.0a |
|                                       | 50% 25.40bc 6.53b 16.67bc 11.24b 2.25ab 1.78a 0.0a |
| 3-5mm                                | 10% 28.40bc 5.43b 16.33c 11.27d 2.25a 1.68ab 0.0b |
|                                       | 20% 30.43ab 6.57ab 17.40bc 15.28bc 2.30a 1.77a 0.3ab |
|                                       | 30% 31.07ab 7.13a 18.83ab 17.46ab 2.32a 1.77a 0.7ab |
|                                       | 40% 32.80a 7.93a 21.00a 17.98a 2.35a 1.75a 1.7a |
|                                       | 50% 27.10c 7.33a 15.33c 14.32c 2.28a 1.73ab 0.3ab |
| 0-6mm                                | 10% 21.87c 6.33b 15.00d 8.68abc 2.25b 1.77ab 0.0a |
|                                       | 20% 28.23ab 6.67ab 15.60a 10.30ab 2.37ab 1.67b 0.3a |
|                                       | 30% 30.33a 7.60ab 16.33a 10.94a 2.35ab 1.77ab 0.3a |
3.3. Effects of different substrate treatments on physiological indexes of Potted Rose

3.3.1. Effects of different substrate treatments on chlorophyll content of Chinese rose in pot culture.

It can be seen from Figure 1 that, on the whole, chlorophyll in potted rose leaves increased after construction waste particles were added to the soil. The chlorophyll content in groups 0-2mm, 2-3mm and 3-5mm all showed a trend of first increasing and then decreasing with the increase of proportion of construction waste particles. There was no obvious rule of change in groups 0-6mm. When the maximum chlorophyll content in each group appeared at 40%0-2mm, 40%2-3mm, 40%3-5mm and 50%0-6mm, it increased by 80.60%, 87.72%, 104.11% and 119.45%, respectively, compared with CK.

3.3.2. Effects of different substrate treatments on nutrient uptake of Nitrogen, Phosphorus and potassium in Chinese rose.

As can be seen from Figure 1, adding construction waste to the soil can increase the total nitrogen content of potted rose plants. The total nitrogen content in each treatment group was significantly higher (P<0.05) than CK, 0-2mm, 2-3mm, and 3-5mm groups all increased with the increase in the proportion of construction waste. The total nitrogen content in the 0-6mm group showed a trend of first increasing and then decreasing, while the change rule in the 0-6mm group was not obvious. The maximum value in each group was found to be 30%-2mm, 40%-3mm, 3-5mm40%, and 40%-6mm, respectively, which were 68.40%, 82.98%, 124.92%, and 59.74% higher than CK. After adding construction waste, the total phosphorus content of potted rose plants also increased to a certain extent. With the increase of the proportion of construction waste in groups 0-2mm, 2-3mm and 3-5mm, the total phosphorus content showed a trend of first increasing and then decreasing. The change rule of 0-6mm group was not obvious. The maximum value appears in 40%3-5mm, which is 91.74% higher than CK. After adding construction waste into the soil, the total potassium content of all treated potted rose was significantly increased (P<0.05). With the increase of the proportion of construction waste, the total potassium content in the 0-2mm, 2-3mm and 3-5mm groups showed a trend of first increasing and then decreasing, while the total potassium content in the 0-6mm group showed a trend of fluctuating increasing. When the peak value still appears at 40%3-5mm, it is 74.31% higher than CK.
3.4. Comprehensive evaluation of the growth of Chinese rose treated with different substrates

Different substrates were used to treat the growth of Chinese rose, and the differences of growth indicators were not consistent, which required comprehensive evaluation. The evaluation results are shown in table 4 and table 5. From the perspective of particle size analysis, 3-5mm, 2-3mm, 0-6mm, 0-2mm. From the perspective of application proportion analysis, 40%, 30%, 20%, 50%, indicating that the treatment with particle size of 3-5mm is better than the treatment with other particle sizes, and the treatment with a proportion of 40% is better than the treatment with other proportions.

Table 4. Comprehensive evaluation index of the growth of Chinese rose with different grain sizes

| Treatment | Plant height /mm | Stem diameter /cm | Root length /cm | Root fresh weight /g | Leaf length /cm | Leaf width /cm | Total flowers | Chlorophyll | Total nitrogen | Total phosphorus | Total potassium |
|-----------|------------------|-------------------|-----------------|----------------------|----------------|---------------|--------------|-------------|---------------|-----------------|---------------|
| 0-2mm     | 0.39             | 0.51              | 0.57            | 0.39                 | 0.24           | 0.55          | 0.04         | 0.39        | 0.20          | 0.49            | 0.54          |
| 2-3mm     | 0.47             | 0.63              | 0.67            | 0.53                 | 0.35           | 0.43          | 0.13         | 0.39        | 0.32          | 0.56            | 0.47          |
| 3-5mm     | 0.71             | 0.70              | 0.66            | 0.75                 | 0.38           | 0.39          | 0.20         | 0.58        | 0.40          | 0.55            | 0.70          |
| 0-6mm     | 0.50             | 0.73              | 0.52            | 0.36                 | 0.48           | 0.41          | 0.04         | 0.53        | 0.30          | 0.42            | 0.17          |

Table 5. Comprehensive evaluation index of the growth condition of potted rose treated with different proportion

| Treatment | Plant height /mm | Stem diameter increment /mm | Root length /cm | Root fresh weight /g | Leaf length /cm | Leaf width /cm | Total flowers | Chlorophyll | Total nitrogen | Total phosphorus | Total potassium |
|-----------|------------------|-----------------------------|-----------------|----------------------|----------------|---------------|--------------|-------------|---------------|-----------------|---------------|
| 10%       | 0.29             | 0.43                        | 0.51            | 0.38                 | 0.28           | 0.42          | 0.00         | 0.34        | 0.16          | 0.28            | 0.23          |
| 20%       | 0.51             | 0.59                        | 0.58            | 0.52                 | 0.33           | 0.40          | 0.08         | 0.44        | 0.24          | 0.50            | 0.52          |
| 30%       | 0.66             | 0.74                        | 0.65            | 0.64                 | 0.37           | 0.45          | 0.17         | 0.52        | 0.45          | 0.54            | 0.50          |
| 40%       | 0.70             | 0.80                        | 0.75            | 0.64                 | 0.39           | 0.46          | 0.25         | 0.56        | 0.54          | 0.71            | 0.63          |
| 50%       | 0.44             | 0.66                        | 0.52            | 0.37                 | 0.43           | 0.49          | 0.03         | 0.49        | 0.14          | 0.50            | 0.45          |

4. Results and Discussion

The purpose of this study was to investigate the effects of different particle sizes and proportions of construction waste on the growth characteristics of Chinese rose potted in different substrates of construction waste and soil in different proportions. The results showed that construction waste had a significant improvement effect on the bulk density and porosity of clay soil, and the grain size and addition ratio of construction waste were positively correlated with soil porosity. Among them, construction waste with a grain size of 3-5mm had the most significant improvement effect on soil bulk density and porosity, which was conducive to the growth of potted rose. Except for no significant effect on the leaf morphology (leaf length and leaf width) of potted rose, plant height, stem diameter, root length, root weight, total flower number, chlorophyll and nitrogen, phosphorus and potassium contents...
of three nutrient elements in potted rose compared with CK all played a significant role, but the specific promotion rules were different.

From the perspective of leaf plant height and stem diameter increment, the promotion effect of the 2-3mm group and the 3-5mm group was relatively obvious, and the maximum value and comprehensive evaluation index of plant height and stem diameter increment were the highest in the 3-5mm group, with a stable change rule. Adding an appropriate amount of construction waste into the soil has a significant promotion effect on the root length and root fresh weight of potted rose. The maximum value appears in the 3-5mm group, and the highest comprehensive evaluation index is also in the 3-5mm group, with obvious and regular promotion effect. The addition of construction waste into the soil has a certain promoting effect on the increase of the total number of flowers. However, due to the low content of nutrient elements supporting the good growth of flowers in the substrate, it is difficult to make the potted rose ornamental to a better degree.

The chlorophyll content of potted rose was also significantly increased compared with CK, which enhanced the photosynthetic rate and improved the stress resistance and nutritional status of potted rose. In each treatment, the peak leaf green content appeared when the particle size was 40%-3-5mm. The content of available potassium in construction waste is relatively high. After adding appropriate amount of construction waste, it can promote the absorption of nitrogen, phosphorus and potassium in the potted rose. When 40% is 3-5mm, the nitrogen absorption promotion effect is the best. The peak value of total phosphorus also appears at 40%-3-5mm; Different matrix treatments had an obvious effect on the total potassium content, and the optimal comprehensive evaluation was still 3-5mm group. From the perspective of proportion, except for blade length and blade width, the highest comprehensive evaluation index of all other indicators is 40%. This is because, on the one hand, adding proper amount of construction waste can effectively improve soil structure, reduce soil bulk density and improve soil permeability, so as to promote the growth of potted rose root system. The more developed the root system is, the better the plant growth condition is [14], which is the same as the research results of Zhu Zhaohua et al. [15]. Green matrix plants with construction waste can grow well. On the other hand, the content of alkali-hydrolyzed nitrogen and available phosphorus in construction waste is not high, so too much construction waste cannot meet the growth demand of potted rose.

5. Conclusion

Based on the above analysis, it can be seen that adding an appropriate amount of construction waste as a modifier in the coastal viscous soil can effectively improve the physical and chemical properties of the coastal viscous soil and better meet the substrate characteristics required by plant growth. Compared with CK, the substrate treated with different treatments had a significant promotion effect on plant height, ground diameter increment, root length, fresh root weight, total flower number, chlorophyll content and nutrient element content of the potted rose. However, excessive construction waste added would have a certain inhibitory effect on the growth of the potted rose. The particle size with the best promoting effect was 3-5mm, followed by 2-3mm. When the particle size is 0-2mm, the improvement ability of soil porosity is relatively weak due to the small particle size, and the promotion effect is relatively weak. When the particle size is 0-6mm, the regularity of the promotion effect is not obvious due to the large span of particle size and the uneven distribution of components. The best proportion is 40%, followed by 30%. Since only soil and construction waste are used in this study, they cannot meet the needs of good plant growth in practical application. Therefore, the particle size and proportion with better promoting effect obtained according to this study can be used to cooperate with other landscaping planting substrates for in-depth study, so as to obtain a more scientific and reasonable utilization way of construction waste as a new type of environmental protection landscaping substrates. This study adopts pot experiment, which is different from the external growth environment to some extent, and needs further study for its application in the field. However, it has certain guiding significance and application value for the recycling of urban construction waste, the improvement of coastal sticky heavy soil and the study of new landscaping matrix.
Acknowledgments
This paper is one of the phased achievements of the national key R & D project (2020YFC1808802), Shanghai Science and Technology Promotion Association Alliance Plan (LM2019-72), Shanghai Science and Technology Commission (17DZ1202402), and key technology research and application of "coastal saline alkali soil ecological sustainable green landscape construction" (15dz1207904).

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