Application of red clay improved with sand at the foot of mountain in subgrade filling

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Abstract—There is a large amount of red clay along a highway under construction in Southwest China. The red clay has high plasticity and small CBR which don’t meet the specification. Therefore, red clay often needs to be improved before being used as filler. This paper proposed a new subgrade filling technology of improved red clay with sand at the foot of mountain. The filling technology has three stages, four sections and eight processes. The improved red clay with sand at foot of mountain was used in a highway. The ratio of sand at foot of mountain to red clay was 4:6. After compaction, the degree of compaction could meet the designed compactness requirements. The improved red clay with sand at foot of mountain has achieved good application effect in the project.

1. INTRODUCTION
Red clay is a kind of clay formed by laterization of carbonate rock outcrop [1]. It is brown red or yellow brown clay with high plasticity, low strength [2]. Red clay generally has a high liquid limit and is easy to shrink due to water loss. Red clay is easy to cause some engineering accidents, such as pavement uplift, uneven deformation of foundation, slope instability, pavement cracking and building deformation [3-5]. It brings a lot of economic losses every year. Therefore, red clay often needs to be improved as subgrade filler[6]. In this paper, a new improvement method is applied to the construction of a highway in Guangxi province. In the new method, sand at the foot of mountain was mixed in red clay when it is used as roadbed filling.

2. ENGINEERING SURVEY
The highway is located in Southwest China. The local climate is monsoon subtropical, with long summer and short winter, small temperature difference, abundant rainfall, four distinct seasons, long
summer and rainy, and annual average temperature of 19.2-21.3 °C. January is the coldest month with an average monthly temperature of 8.5 °C, July is the hottest month with an average monthly temperature of 28.5 °C. The annual average rainfall is over 1300 mm, and the rainfall is concentrated between May and September.

There is a large amount of red clay along the highway. Its properties are shown in table 1. “Specifications for Design of Highway Subgrade JTG D30-2015” specifies the properties of red clay that can be used as subgrade filler, as shown in table 2.

As can be seen from table 1 and table 2, only the plasticity index of red clay in the highway meets specification requirements. The California bearing ratio (Referred to as "CBR") and the liquid limit can’t meet specification requirements. The red clay can’t be directly used as highway filler without improvement. Therefore, the red clay was improved with sand at the foot of mountain in the project.

### TABLE 1. PROPERTIES OF RED CLAY

| Moisture Content (%) | Proportion | density(g/cm³) |
|----------------------|------------|---------------|
| Wet                  | Dry        |               |
| 30.2                 | 2.76       | 1.88          |
| Liquid limit (%)     | plastic limit (%) | Plasticity index | CBR(%) |
| 53.9                 | 29.4       | 24.5          | 2.24   |

### TABLE 2. SPECIFICATION FOR RED CLAY SUBGRADE FILLER

| Subgrade position         | Depth below pavement bottom (m) | Minimum CBR (%) | Maximum liquid limit (%) | Maximum plasticity index |
|---------------------------|----------------------------------|-----------------|--------------------------|--------------------------|
| Upper road bed            | 0–0.3                            | 8               | 50                       | 26                       |
| Lower road bed            | 0.3–1.2                          | 5               | 50                       | 26                       |
| Upper embankment          | 0.8–1.9                          | 4               | 50                       | 26                       |
| Lower embankment          | 1.5 or less                      | 3               | 50                       | 26                       |

3.IMPROVEMENT METHOD OF THE RED CLAY

Sand at the foot of mountain in this project is a kind of natural sand which is deposited in situ after weathering[7], as shown in figure 1. The particles are mostly angular with rough surface, but the sand contains clay, soft particles, organic substances and other harmful impurities, which usually can’t be used as fine aggregate of concrete. However, it is excellent subgrade filling materials.

Figure 1. Field mixing of improved red clay with sand at foot of mountain.
The sand production area is close to the construction area in this project. It is more economical to improve the red clay by mixing the sand at foot of mountain than by mixing the river sand and lime. In another paper of the author, the proportion of sand at the foot of mountain is studied. The result shown that the most suitable ratio of sand to soil was 4:6. Properties of improved red clay were shown in table 3. As can be seen from table 1~table 3, liquid limit and plasticity index of the red clay decreased after improved by mixing sand at foot of mountain. The CBR increased after improvement. Liquid limit, plasticity index and CBR of the improved red clay all meet the specification. The red clay improved with sand at the foot of mountain can be used as subgrade filling materials.

| Table 3. Properties of Improved Red Clay |
|----------------------------------------|
| CBR (%) | liquid limit (%) | plasticity index |
| 28.1    | 45.6             | 21.8             |

4. FILLING TECHNOLOGY OF RED CLAY SUBGRADE
A set of red clay filling technology has been formed in the project. The filling technology has three stages, four sections and eight processes, as shown in figure 2. The filling technology is generally divided into preparation stage, construction stage and renovation acceptance stage. Along the roadbed, the filling technology can be divided into filling section, leveling section, rolling section and detection section. Each section can be constructed in parallel. Each section can be divided into construction reparation, substrate processing, layered filling, paving and levelling, watering and drying, rolling compaction, test and detection and roadbed dressing.

A new mixing technology of improved red clay is put forward. The key point of the technology is to control the site stacking according to the ratio of red clay and sand at the foot of the mountain obtained from experiment, use the excavator to mix on site for many times, use graders or bulldozers to bulldoze, then with use the rotary ploughs to mix evenly, and finally use compactors to roll. Figure 1 is a picture of field mixing of improved red clay.

5. APPLICATION EFFECT OF IMPROVED RED CLAY
The vibrating roller in the project adopted XP222 22T, and the rolling speed is 2km/h ~ 4km/h. The thickness of loose paving is 30cm. In this case, the mechanical utilization rate is the highest. Compaction degree is used as the main control index of red clay filling in the project. After compaction, the compactness of the improved red clay with sand at foot of mountain in the project can meet the design requirements.
When the degree of compaction is 93%, static pressure shall be applied for one time, vibration rolling for four times and static pressure for one time. When the degree of compaction is 94%, static pressure shall be applied for one time, vibration rolling for five times and static pressure for one time.

When the natural water content is about equal to the optimum water content, it is better to pave and roll directly. When the moisture content of the soil is too large, it is necessary to pave and air dry it. It is absolutely not suitable to pave and roll it directly, otherwise it will only turn over in a large area.

6. Conclusions

In this paper, subgrade filling technology of improved red clay with sand at foot of mountain is studied. Flowing result were obtained.

(1) When red clay is modified in the highway, the ratio of sand at foot of mountain to red clay was 4:6.

(2) A new subgrade filling technology of improved red clay with sand at the foot of mountain was proposed. The filling technology has three stages, four sections and eight processes.

(3) A new mixing technology of improved red clay is put forward. The key point of the technology is to control the site stacking according to the ratio of sand and red clay obtained from experiment, use the excavator to mix on site for many times, use graders or bulldozers to bulldoze, then with use the rotary ploughs to mix evenly, and finally use compactors to roll.

(4) When the degree of compaction is 93%, 6 times of compaction are needed. When the degree of compaction is 94%, 7 times of compaction are needed.

(5) After compaction, the degree of compaction could meet the designed compactness requirements. The improved red clay with sand at foot of mountain has achieved good application effect in the project.

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