# Applicability of Tunnel Muck as An Alternative for Fine Aggregates in Cement Concrete

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**Abstract**

One of the recent applications of Tunnel boring Machines (TBM) in Sri Lanka is Uma Oya Multipurpose Development Project (UOMDP). During rainy periods, the washed tunnel muck particles sediment in low agricultural lands forming infertile soil. It mainly affects the agricultural sector in the respective area of the country. Therefore, it appears that there is a need to study the reuse of the tunnel muck as an alternative for sand which is a very expensive construction material these days, or any other field as a useful material in an effective manner. The objective of this study is to determine the applicability of tunnel muck as an alternative for sand in concrete as fine aggregate. The material properties of tunnel muck were analysed. Water absorption and workability were higher in the concrete mixed with tunnel muck because the tunnel muck particles are finer than normal sand particles. It was observed that there was a slight decrease in the compressive strength of the concrete casted with tunnel muck. However, the compressive strength could be increased with higher cement content in the concrete. Furthermore, the mix designs with adjusted values were proposed for the concrete mixed with tunnel muck as fine aggregates.

**Keywords:** Mix designs, River sand, Tunnel boring machine

## 1. Introduction

It can be identified two main tunnel excavation methods in the tunnel construction industry, as drilling and blasting (D&B) and Tunnel Boring Machine (TBM). Uma Oya Multipurpose Development Project (UOMDP) is one of the recent applications of TBM. It can be observed that a large amount of tunnel muck has been placed in UOMDP, and currently, it has caused severe environmental and agricultural issues [1]. The washed tunnel muck particles are transported with the runoff water during rainy periods and deposits in low land areas causing infertile soils for agricultural activities [1].

As a solution to this, the removed tunnel muck can be used as an alternative in the construction industry or any other industry [2]. Therefore, it appears that the research studies have to be carried out to determine the applicability of tunnel muck

as an alternative for construction material in the construction industry.

River sand is normally used as the fine aggregates of cement concrete, and it is one of the major ingredients of cement concrete [3]. However, the demand for the river sand is very high, and the cost for the cement concrete would be reduced if an alternative for the river sand is introduced. That kind of alternative would support the protection of the riverbeds where the river sand is mined.

Here in this study, the applicability of tunnel muck as an alternative for the river sand is determined, and it is analyzed using basic parameters used in cement concrete.

## 2. Objectives

The objectives of this research are:

- To determine the applicability of Tunnel Muck at Uma Oya Tunnel as a fine aggregate for concrete.
- To determine the properties of concrete made with the tunnel muck removed as a waste of UOMDP.
- To compare the properties of concrete with different water-cement ratio values.

This study consists of a comparison of the test results that have been carried out in laboratories on concrete samples to determine the applicability of tunnel muck as an alternative to river sand and the optimum mix ratio of tunnel muck to achieve the maximum characteristics of concrete.

## 3. Methodology

Tunnel muck samples are collected from the UOMDP site, and firstly they are tested for sieve analysis. The results are checked with the standard limit range for the particle size distribution curve as per BS 882:1973. Furthermore, the concrete samples made with river sand and the samples made with tunnel muck were tested for the basic tests for concrete, and the results are analyzed.

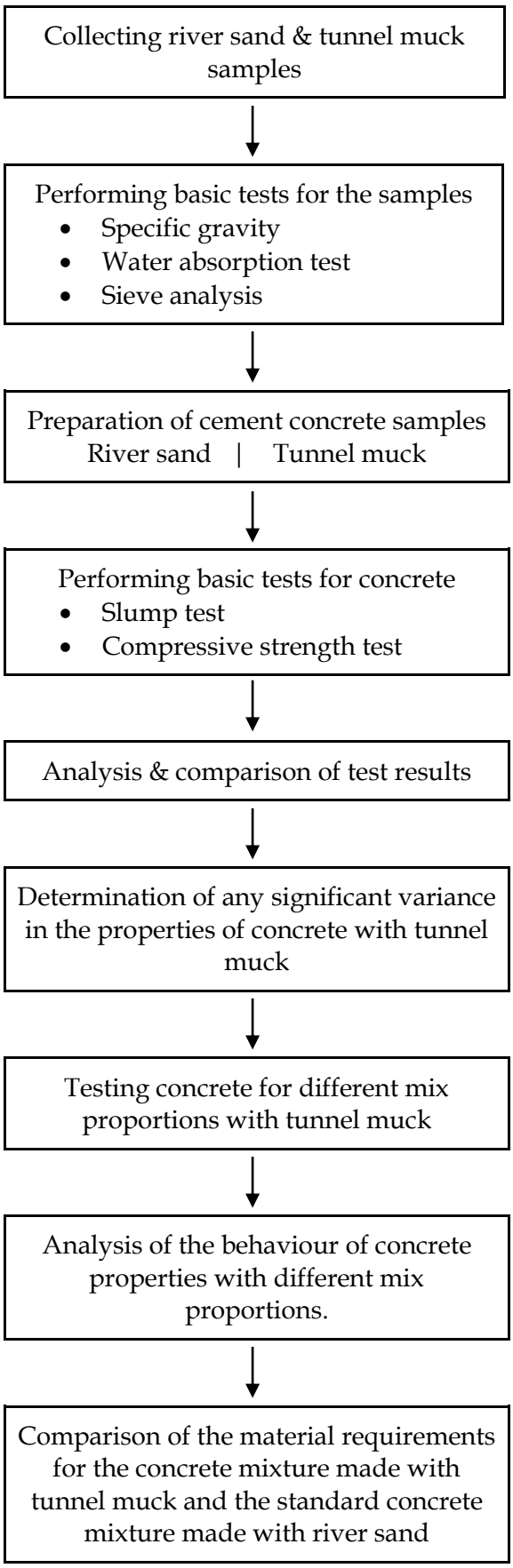


***Figure 1: Methodology.***

The results are compared with the values available in the literature to determine whether the addition of tunnel muck makes

a considerable deviation. The behavior of the concrete made with tunnel muck was observed by changing the mix proportions.

## 4. Results and Analysis

### 4.1 Sieve analysis test

Sieve analysis tests were carried out for both tunnel muck and river sand samples to check the applicability in accordance with BS 882:1993 (Grading of fine aggregates). A representative sample of 0.6 kg from tunnel muck and 1 kg of river sand were used for the analysis. Figure 2 shows the results of the sieve analysis.

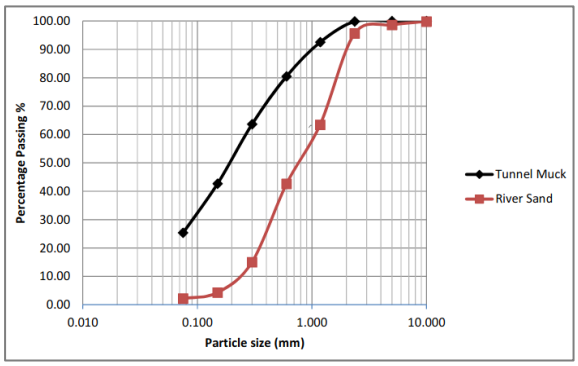


***Figure 2: PSD curve for tunnel muck and river sand.***

It was observed that the particle size distribution (PSD) of selected river sand samples was within the acceptable limit range (in zone 2) mentioned in BS 882:1973. However, the PSD of the selected tunnel muck sample was not within the acceptable range.

### 4.2 Specific gravity and Water absorption test

Specific gravity tests and water absorption tests were carried out for both tunnel muck and river sand samples. The results are as follows,

Tunnel muck:

Specific gravity = 2.64

Water absorption = 2.49%

River sand:

Specific gravity = 2.65

Water absorption = 0.60%

It appears that the specific gravities of both materials were almost the same. However, the water absorption of tunnel muck is considerably higher than river sand.

Further, the specific gravity and water absorption values of coarse aggregates (nominal size = 20 mm) were determined for the use in mix designs.

### 4.3 Slump test

Mix designs were carried out for each grade of concrete with river sand and tunnel muck. The results of slump tests for each grade of concrete are tabulated in Table 1.

***Table 1: Slump test results.***

| Grade | With River sand (mm) | With Tunnel muck (mm) |
|---|---|---|
| M10 | 63 | 81 |
| M15 | 61 | 78 |
| M20 | 54 | 90 |

It was observed that the slump values of concrete made with tunnel muck are relatively higher compared to the river sand for the considered grades of concrete. Further, it was noticed that the concrete made with river sand has a low to medium workability and the concrete made with tunnel muck has a medium to high workability (BS 882:1973).

### 4.4 Compressive strength test

Compressive strength was tested for the concrete made with river sand and tunnel muck for 7 days and 28 days. The average values are compared in Figures 3 and 4.

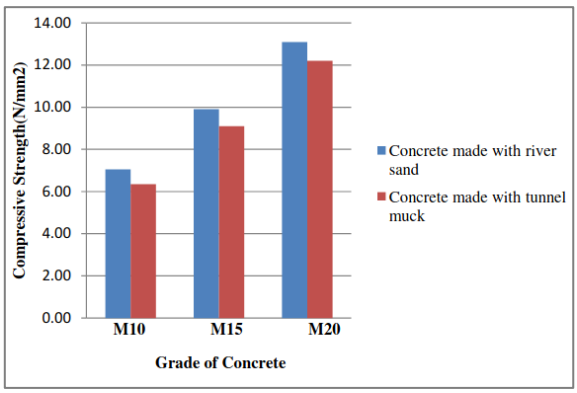


***Figure 3: Results of compressive strength test (7 days).***

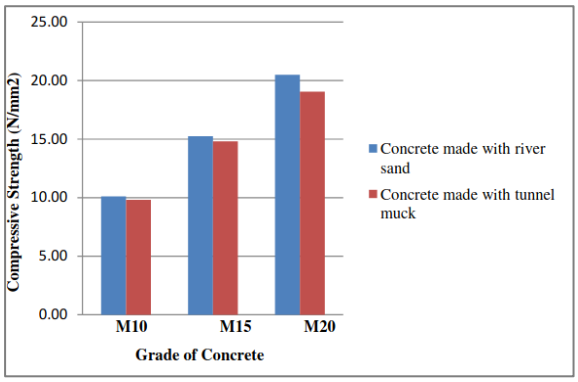


*Figure 4: Results of compressive strength test (28 days).*

### 4.5 Results for adjusted mix design

It was observed that the compressive strengths of all considered grades of concrete are lower in the concrete made with tunnel muck. Therefore, the mix designs were adjusted by decreasing the water-cement (w/c) ratio. The adjusted w/c ratio values are tabulated in Table 2 with the initial w/c ratio values.

*Table 2: Adjusted w/c ratio values.*

| Grade | Initial w/c ratio | Adjusted w/c ratio |
|---|---|---|
| M10 | 0.85 | 0.5 |
| M15 | 0.80 | 0.5 |
| M20 | 0.75 | 0.5 |

The compressive strength was tested for the concrete made with the adjusted mix proportions by decreasing the w/c ratio. The results are compared with the compressive strength values of concrete made with river sand and depicted in Figures 4 and 5.

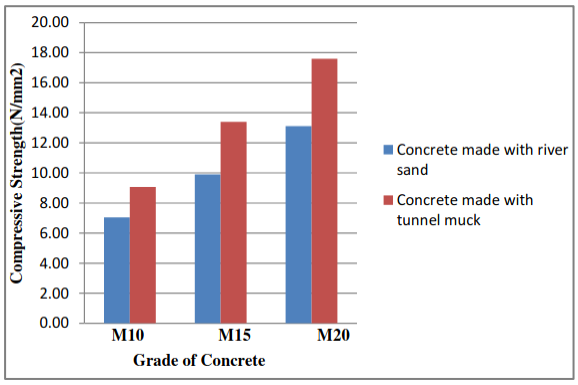


*Figure 4: Results of compressive strength test (7 days) for adjusted mix proportions.*

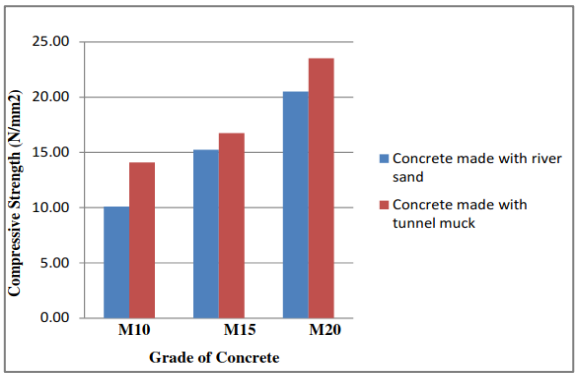


*Figure 5: Results of compressive strength test (28 days) for adjusted mix proportions.*

It was noticed that the compressive strength was increased by 45% on average in 7 days and 25% on average in 28 days of concrete made with tunnel muck using adjusted w/c values.

## 5. Discussion

This research was carried out as an experimental study to investigate the applicability of tunnel muck as an alternative for fine aggregate in concrete.

As per the results of the sieve analysis test, it was noticed that tunnel muck is finer and poorly graded relative to the river sand. Further, the particle size distribution of tunnel muck is not compatible with any zone mentioned in BS 882:1973. However, the availability of finer particles may cause higher workability of the tunnel-muck concrete.

In this study, a higher w/c ratio was initially selected to study the behavior of the strength of concrete at a higher w/c ratio with tunnel muck. It was observed lower compressive strength for higher w/c ratio and higher compressive strength in low w/c ratio. Therefore, the targeted compressive strength can be obtained by using tunnel muck by optimizing the w/c ratio further.

The sample collected site was infected by an environmental issue that the low land areas are becoming infertile due to the transportation of tunnel muck. Therefore, the use of tunnel muck as an alternative to river sand would be a good solution. However, the chemical composition of the concrete with tunnel muck and the effects will have to be investigated.

## 6. Conclusions

Based on the experimental results, the following conclusions could be drawn as the outcome of this study.

- The workability is higher in the concrete made with tunnel muck.
- The target strength cannot be achieved by the tunnel-muck concrete with a higher w/c ratio. However, the target strength can be achieved by a low w/c ratio (i.e., high cement content).

The Following can be recommended as further developments for this topic.

- Determination of an optimum mixture of tunnel muck and river sand for optimum properties of concrete.
- Determination of the optimum proportion of tunnel muck for reinforced concrete and precast concrete.
- Study about the chemical composition of the tunnel muck and the behavior of the concrete based on chemical composition.
- Determination of strength parameters of concrete made with tunnel muck by adding admixtures and for grades higher than M20.

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