

# ENHANCEMENT OF UNCONFINED COMPRESSIVE STRENGTH (UCS) VALUES OF RECLAIMED ASPHALT PAVEMENT (RAP) FOR USING IT AS SUBBASE / BASE COURSE OF FLEXIBLE PAVEMENT

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## ABSTRACT

Reclaimed Asphalt Pavement (RAP) materials are generally obtained during rehabilitation, strengthening and upgradation of existing flexible pavement. Generally high quality RAP materials having uniform properties are intended to use for preparation of Hot Mix Asphalt (HMA). However, RAP materials which are not suitable for reusing in the preparation of HMA are generally intended to use in Subbase / Base course of flexible pavement. The present study is to assess the suitability of using RAP materials obtained from milling / full depth rehabilitation of existing flexible pavement as potential subbase / base course for new flexible pavement construction. As per Indian Road Congress (IRC) recommendation, unconfined compressive strength (UCS) value of treated aggregates shall be in the range of 1.50 Mpa-3Mpa and 4.50 Mpa -7Mpa for its use as subbase and base of flexible pavement respectively. It is observed from the present study that though UCS values of 100% RAP is very low (55kpa), it is increased upto 4 Mpa when mixed with suitable proportion of Crushed stone aggregates and stabilizing with various percentages of cement thereby making it suitable for its use as subbase / base course of flexible pavement. Modified proctor compaction tests were conducted on both RAP and mixture of RAP and crushed stone aggregates to established optimum moisture content (OMC) for the preparation of UCS samples. Similarly grain size analysis was also done for RAP and mixture of RAP with crushed stone aggregates.

**KEY WORDS:** Reclaimed Asphalt Pavement; unconfined compressive strength; Crushed stone aggregates

## INTRODUCTION

In the present study, series of laboratory tests have been done on Reclaimed Asphalt Pavement (RAP), Crushed Stone Aggregates and mixture of the same with various proportions with small percentages of cement. In the present study, Grain size analysis have been done on RAP and crushed stone aggregates and observed that combined gradation of 50% RAP+50% Crushed Stone Aggregates (CSA) comes closer to the requirement of base course gradation as per specification of Ministry of Road Transport & Highways (MoRT&H). Modified Proctor Compaction Tests have been done on RAP, RAP-CSA mix to establish the optimum moisture content requirement for achieving maximum dry density. Samples for conducting unconfined compressive Strength (UCS) tests have been prepared based such OMC values. UCS tests have been conducted on RAP, RAP +CSA mix and RAP+CSA mix with various percentages of cement.

## MATERIALS

### Reclaimed Asphalt Pavement (RAP)

RAP was procured from nearby National Highway (NH) projects, namely “Surat- Dahisar section of NH-8”. This section of National Highway has been recently widened to six lane from existing 4 lane for a project length of 245 km. This project being strengthening and widening of existing bituminous pavement, Reclaimed Asphalt Pavement (RAP) was produced during milling operation of existing pavement while strengthening for the same. The Compacted dry density of RAP is observed as 1.98 gm/cc and Bituminous content in RAP is recorded as 3.2%. Grain Size of RAP is observed as 100% passing 37.5mm Sieve. CBR value of RAP is observed about 8.5% - 20%. However, The CBR value of RAP is increased in excess of 100% when mixed with crushed stone aggregates and certain percentage of cement. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) as per standard proctor tests have been observed as 2.25 gm/cc and 5.2 % respectively. Photographs of RAP as collected for various laboratory tests are indicated in Fig. 1.

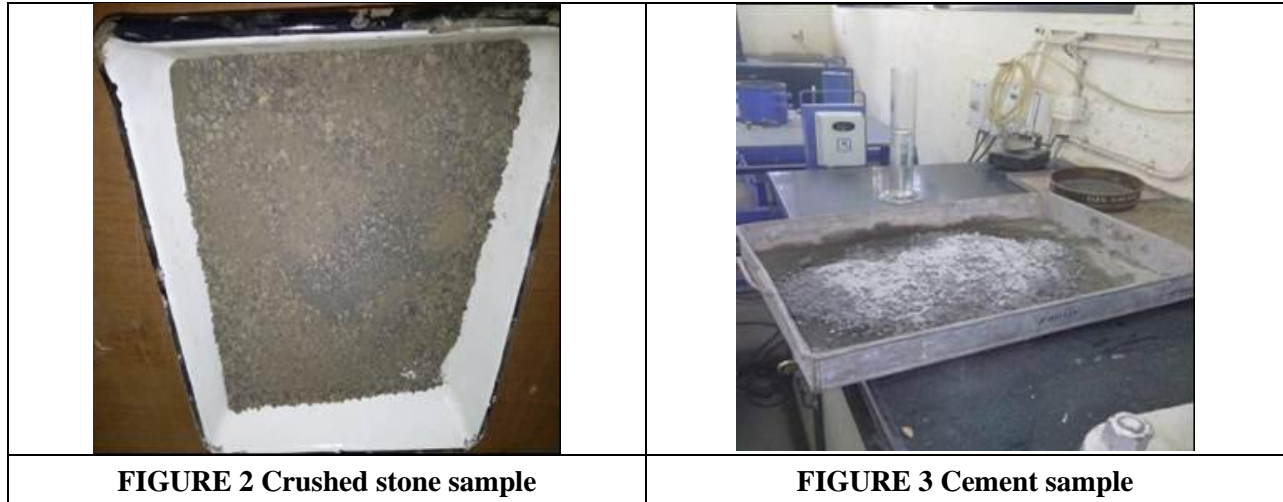


**FIGURE 1 RAP sample**

### Crushed Stone Aggregates (CSA)

Strength of Reclaimed Asphalt Pavement (RAP) materials in terms of California Bearing Ratio (CBR) increases when it is blended with virgin aggregates, as observed from past studies of various researchers. Accordingly it was decided to blend RAP with virgin aggregate in different proportions. However instead of considering wet mixed macadam (WMM) as virgin aggregate, crushed stones have been considered as virgin aggregates due to cost considerations. Crushed stone aggregates for this experiment have been collected from crushers installed for Surat-Dahisar project.

The Grain size of crushed stone aggregates is observed as 100% passing 3.75mm sieve. It was found as Non plastic granular material. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) as per standard proctor tests have been observed as 2.38 gm/cc and 9.2% respectively. California Bearing Ratio (CBR) is observed as 53- 95%. Unconfined Compressive strength is found as 100 kPa - 170 kpa. Photographs of crushed stone aggregates used as crushed stone aggregate for blending with RAP are indicated in Fig.2.



### **Cement**

Commercially available Ordinary Portland Cement (OPC) of grade 43 has been used as stabilizer for RAP as well as RAP- crushed stone aggregate blends. Photograph of cement used is indicated in Fig. 3.

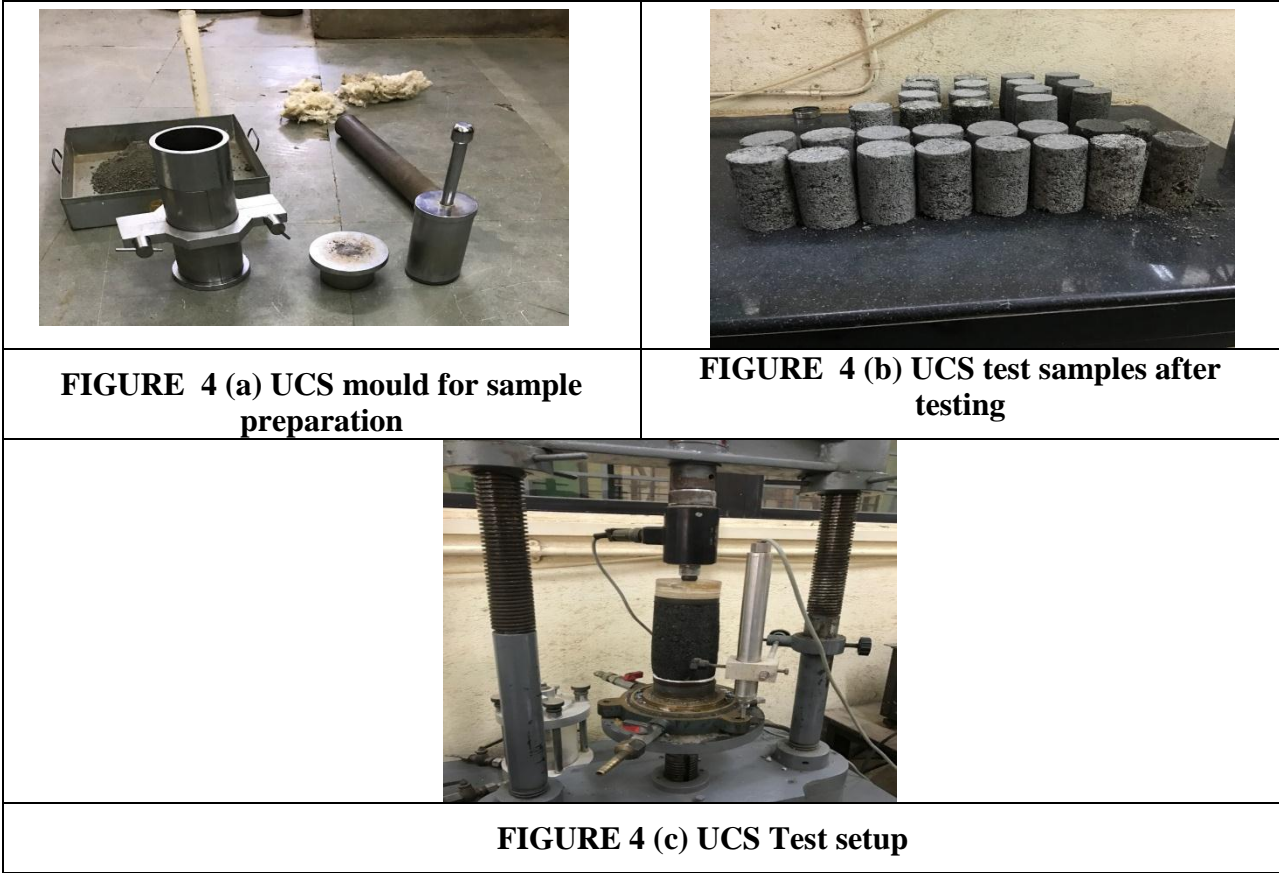
### **Methods**

#### **Unconfined Compressive Strength (UCS) Tests**

UCS tests were done on Reclaimed Asphalt Pavement (RAP) materials and various proportions of RAP and Crushed Stone aggregates (CSA) with / without cement. Specifically, the following combinations of materials were considered for UCS tests:

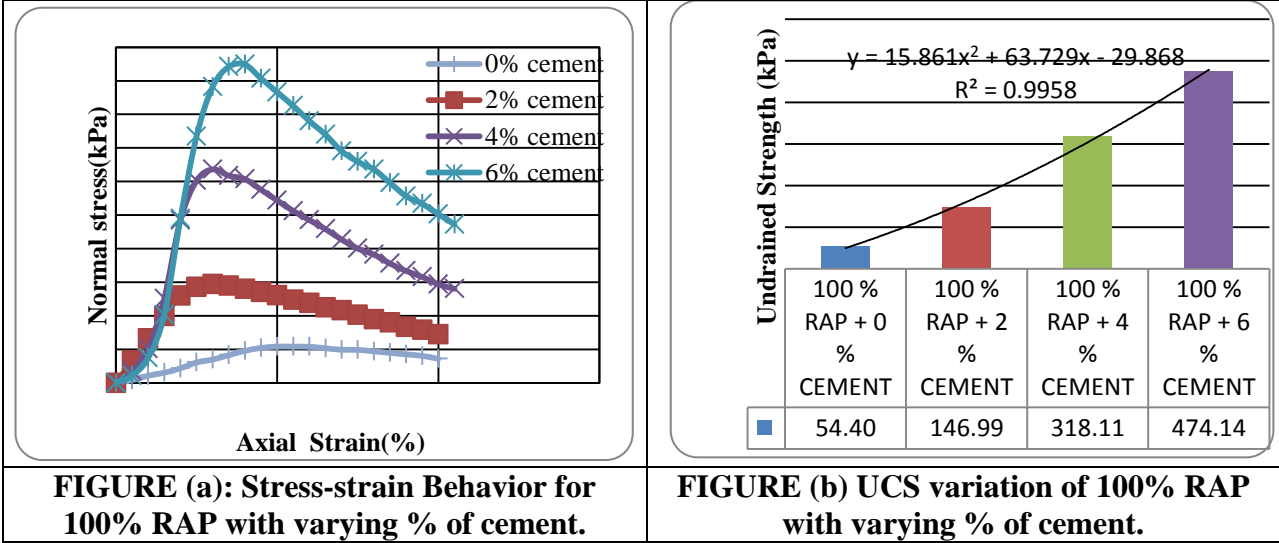
- 100 % RAP with 0%, 2%, 4% and 6% cement
- 75 % RAP + 25 % CSA with 0%, 2%, 4% and 6% cement
- 50 % RAP + 50 % CSA with 0%, 2%, 4% and 6% cement
- 25 % RAP + 75 % CSA with 0%, 2%, 4% and 6% cement
- 0 % RAP + 100 % CSA with 0%, 2%, 4% and 6% cement

2 UCS samples were prepared for each combination of materials. Accordingly, a total of 40 numbers of UCS samples were prepared & tested. UCS samples have been prepared in big size split sampler (75 mm diameter and 150 mm height). Samples have been prepared at Optimum moisture content (OMC) and adequately compacted to achieve maximum dry density (MDD). Initially it was very difficult to get stable UCS samples for testing as samples used to break down while removing from split sampler. Subsequently, measured quantity of materials (RAP, RAP – CSA and cement) were taken and mixed thoroughly with measured quantity of water as per proctor compaction tests results. It was then placed and compacted in layers with adequate compactive efforts. After adequate compaction, split samplers were removed very carefully to get stable samples and kept them for moist curing for 7 days with plastic cover in air tight container. Samples thus prepared have been tested after 7 days in UCS testing machine. Details of UCS mould for Sample preparation, Samples after testing & testing details are indicated in Figure 4.



• **100% RAP**

Results of Unconfined Compressive strength (UCS) tests on 100% RAP with varying percentages of cement are indicated in Fig. 5.



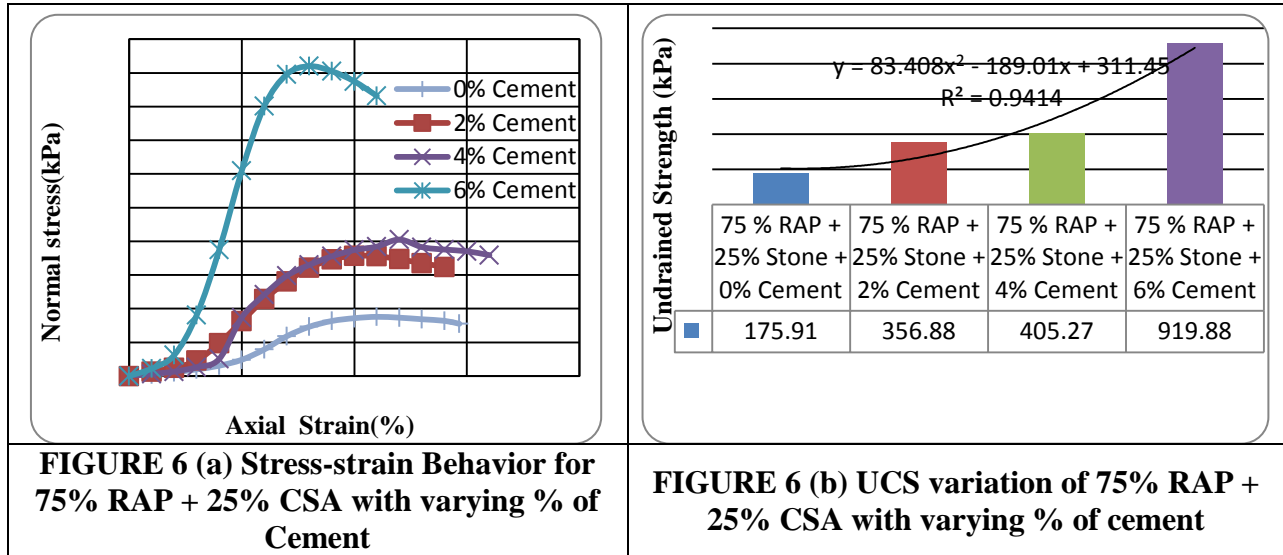
**FIGURE (a): Stress-strain Behavior for 100% RAP with varying % of cement.**

**FIGURE (b) UCS variation of 100% RAP with varying % of cement.**

From Fig. 5, It is observed that, UCS varies from 54.4 kPa to 474.14 kPa for 100% RAP for cement varying from 0-6%.

• **75% RAP + 25% CSA**

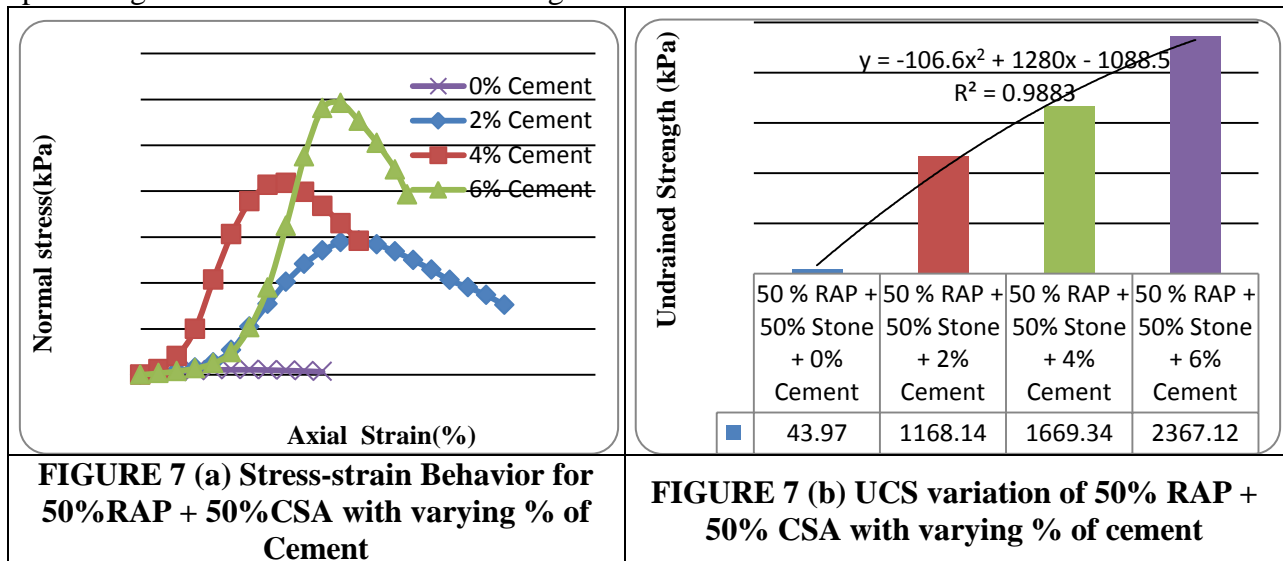
Results of Unconfined Compressive strength (UCS) tests on 75% RAP + 25% CSA with varying percentages of cement are indicated in Fig. 6.



From Fig. 4.71, It is observed that, UCS varies from 139.20 kPa to 955.85 kPa for 75% RAP + 25% CSA for cement varying from 0-6%.

• **50% RAP + 50% CSA**

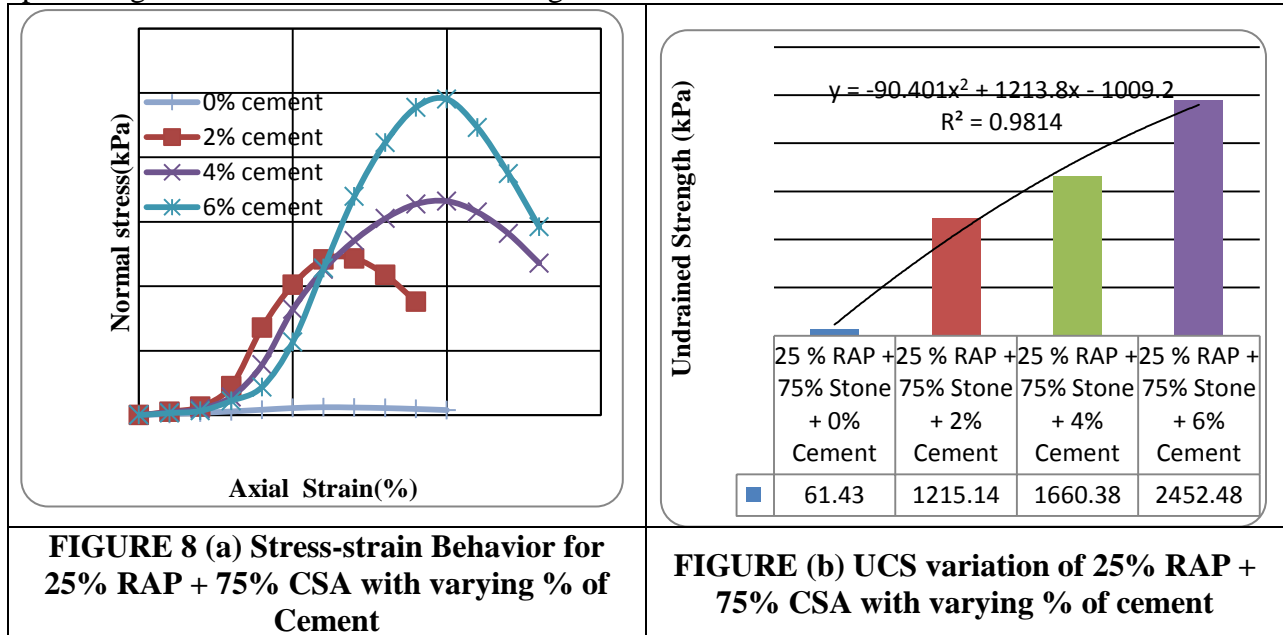
Results of Unconfined Compressive strength (UCS) tests on 50% RAP + 50% CSA with varying percentages of cement are indicated in Fig. 7.



From Fig. 7, It is observed that, UCS varies from 43.97 kPa to 2367.12 kPa for 50% RAP + 50% CSA for cement varying from 0-6%.

• **25% RAP +75% CSA**

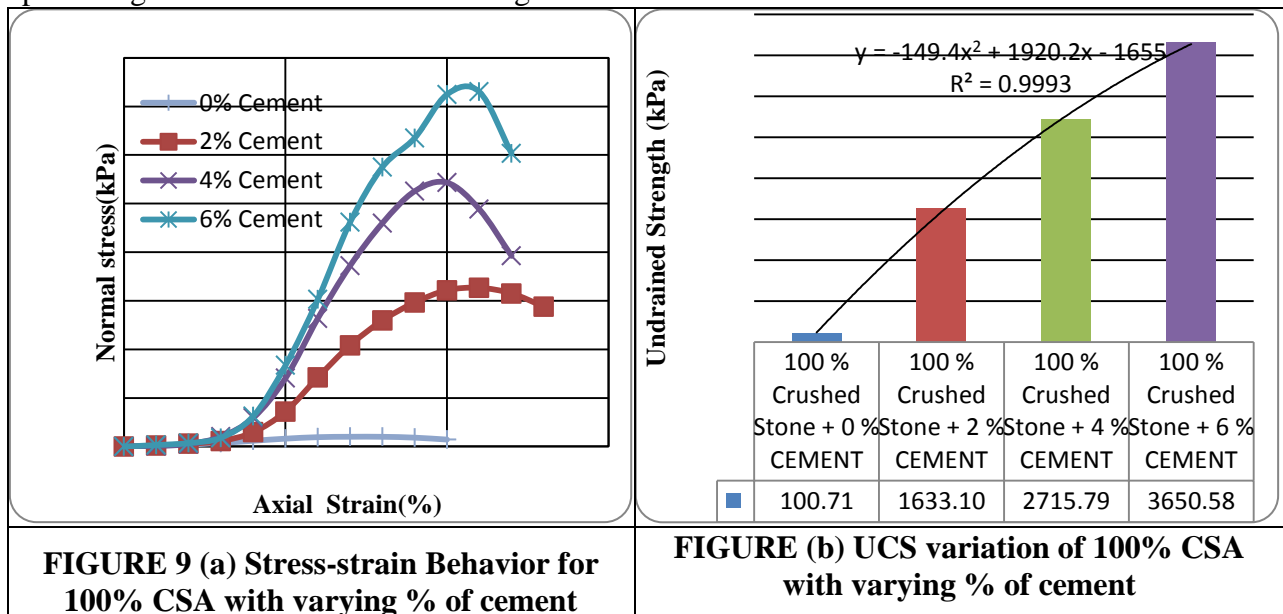
Results of Unconfined Compressive strength (UCS) tests on 25% RAP + 75% CSA with varying percentages of cement are indicated in Fig. 8.



From Fig. 8, It is observed that, UCS varies from 61.5 kPa to 2452.5 kPa for 25% RAP + 75% CSA for cement varying from 0-6%.

• **100% CSA**

Results of Unconfined Compressive strength (UCS) tests on 100% CSA with varying percentages of cement are shown in Fig. 9.



From Fig. 9, It is observed that, UCS varies from 100.7 kPa to 3650.6 kPa for 100% CSA for cement varying from 0-6%.

## DISCUSSIONS AND CONCLUSIONS

- Unconfined Compressive Strength (UCS) increases with decrease in RAP content for a particular cement content.
- Unconfined Compressive Strength (UCS) increases with increase in cement content for a particular RAP content.
- For 100% RAP, UCS value increases for 54.4 kPa to 474.2kPa due to increase in cement content from 0 to 6%.
- For 75% RAP + 25% Crushed stone aggregates, UCS value increases for 139.2 kPa to 955.9 kPa due to increase in cement content from 0 to 6%.
- For 50% RAP + 50% Crushed stone aggregates, UCS value increases for 44.0 kPa to 2367.1kPa due to increase in cement content from 0 to 6%.
- For 25% RAP + 75% Crushed stone aggregates, UCS value increases for 61.5 kPa to 2452.5kPa due to increase in cement content from 0 to 6%.
- For 100% Crushed stone aggregates, UCS value increases for 100.7 kPa to 3650.6kPa due to increase in cement content from 0 to 6%.

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