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# Experimental Analysis on Stability and Indirect Tensile Strength in Asphalt Emulsion Mixture Containing Buton Granular Asphalt

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**Abstract**

Natural rock asphalt which exists in great amount has been processed into small granular size called Buton granular asphalt (BGA). BGA consists of 27% bitumen and 63% mineral, respectively. In this research, BGA was introduced in the asphalt emulsion mixture. There are two stages of mixing. In the first stage, asphalt emulsion mixture without BGA was prepared with cationic slow setting (CSS) emulsion content varied from 4.5% to 6.5% by weight of mixture. Mixture with 5.5% of CSS asphalt emulsion achieved optimum asphalt emulsion content. In the second stage, at optimum asphalt emulsion content, bitumen of BGA was used for petroleum bitumen partial replacement in the asphalt emulsion mixture. Ratio of 0%, 2.5%, 5% and 7.5% were used. Test result revealed that utilizing BGA in asphalt emulsion mixture has proved in improving stability and indirect tensile strength. Stress strain behaviors formed a linear relationship up to strain value approximately of 0.5 x $10^{-3}$ and the peak stress was related to strain value from 4.5 x $10^{-3}$ to 6.5 x $10^{-3}$ regardless to the BGA content in the mixture.

**Keywords:** Buton granular asphalt (BGA), stability, indirect tensile strength, stress-strain relationship

## INTRODUCTION

The increase in number of vehicle increases the emmission quantity and creates a negative impact on the environmental surround the road infrastructur [1]. The contractor as a service provider influences the quality of road construction and has a potential risk of the construction failure in every stage of the project. The contractor failure is always generated from the unskill workers [2]. It is important to use a material that can withstand the negative impact of the vehicle emission, climate, weather action and can be easily used in the road contruction.

In order to pursue the national growth many road infrastructures are built with results the large increment of the bitumen consumption. Indonesia currently consumes 1.2 million tonnes of bitumen which about 600,000 tonnes are locally produced and the rest is imported. A lot of discussion was made on the large amount of the national bitumen import looking for other alternative of refined bitumen. In Buton Island, South-East Sulawesi, Indonesia, a sedimentary rock containing of high hydrocarbon substances exists naturally in large quantities, and it has not been fully utilized for asphalt concrete mixtures. The natural rock asphalt is named as Buton rock asphalt (BRA. The mechanical process has employed on BRA to obtain Buton granular asphalt (BGA) in form on small grains with water content, bitumen content and penetration value those are in accordance with stipulation [3].

Extensive developments have been expended toward characterizing BGA properties and its utilization in road construction. Among the researches on BGA utilization, Gaus, et al [4, 5] carried out an experimental study to evaluate the influence of using BGA with approximately diameter of 1.18 mm as petroleum bitumen partial replacement on the stability and compressive strength of asphalt concrete bearing course (AC-BC) mixture. Experimental results indicated that such BGA mixture achieve a higher stability and compressive strength, compared to asphalt concrete mixture without BGA. Budiamin, et al [6] conducted research on the utilization of BGA with approximately diameter of 9.5 mm to produce hot mix cold laid asphalt concrete. Experimental results revealed that BGA mixture is suitable to be used in the production of hot mix cold laid asphalt concrete.

Marshall test is an empirical laboratory test that widely used to measure of resistance to deformation [7]. As the wheel passes, tensile stress arises in the pavement structure under an approaching wheel load. The tensile strength is conventionally used in pavement engineering practice as one of the key parameters in the prediction or estimation of the mechanical behavior of pavement structures [7]. M.R. Islam, et al [8] carried out indirect tensile strength (ITS) test to evaluate the influence short-term laboratory aging (on loose mixture), long-term laboratory oven aging and field aging on the tensile strength of asphalt concrete. C. S. Du, [9] carried out ITS test to evaluate the cement influence on the tensile strength of asphalt emulsion mixture.

For the past several years, significant researches and inventions have been carried out to improve quality bituminous emulsion compositions and their subsequent application with fulfill the road pavement specification. Most of asphalt emulsions use petroleum bitumen as droplet phase. Production of asphalt pavement using asphalt emulsion mixture is being increasingly encouraged to reduce the environmental impact and energy consumption of pavement construction [10].

In this present paper, an asphalt emulsion made with petroleum bitumen as droplet phase was blended with BGA to increase the amount of bitumen and filler in bitumen emulsion mixture production. The present experimental investigation focuses to determine the influence of partial replacement of petroleum bitumen in asphalt emulsion by bitumen of BGA on the structural integrity of asphalt emulsion mixtures by conducting Marshall stability test and ITS test. Stress strain relationship also studied to understand the elastic limit due to tensile stresses arises in the asphalt emulsion mixture containing BGA and mixture without BGA.

## MATERIALS AND METHODS

### Experimental Program Test

The experimental program test has been carried out in two steps. In the first step, Marshall stabilty of the mixtures without BGA was characterized to determine the optimum content of asphalt emulsion in the mixture. Asphalt emuslsion content varied from 4.5 to 6.5% with an increment of 0.5%. Then in the second step, at an optimum asphalt emulsion content, petroleum bitumen in CSS-1h was partially replaced by bitumen of BGA. Stabilty and ITS tests with stress strain relationship were carried out to study the performance of asphalt emulsion mixture containing BGA.

### Buton Granular Asphalt (BGA)

BGA used in this research has a relatively uniform grain size with a maximum size of 1.18 mm. Figure 1 and Table 1 show dimension of BGA and some properties of BGA type 20/25, respectively.

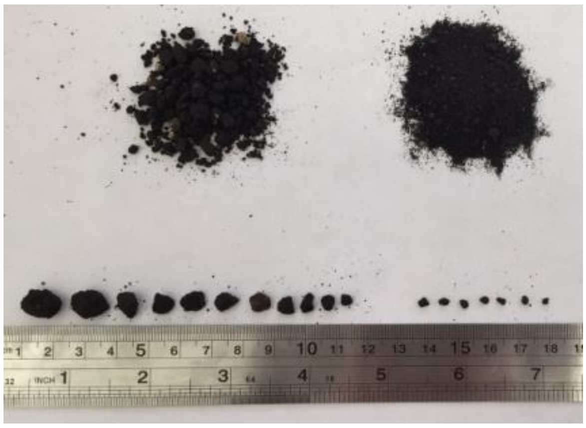

**Figure 1.** Buton Granular Asphalt BGA (dimension in mm)

**Table 1.** Some Properties of Buton Granular Asphalt

| Parameter | Value |
|---|---|
| Bitumen content of BGA (%) | 23.00 |
| Asphalt mineral content (%) | 77.00 |
| Water content (%) | 1.70 |
| Flash point before Extract (mm) | 1.68 |
| Melting point of bitumen BGA Extract ($^0$C) | 86 |

### Characteristics of Asphalt Emulsion

Table 2 shows characteristics of asphalt emulsion CSS-1h used this research.

**Table 2.** Characteristics of Asphalt Emulsion (CSS-1h)

| Kinds of Testing | Testing Result |
|---|---|
| Viscosity, Saybolt Furol 25°C, s | 39 |
| Storage stability, 24-h, % | 0.6 |
| Elementary charge | Positive |
| Sieve test number. 20, % | 0 |
| Distillation | |
| • Water content, % | 36.65 |
| • Oil content, % | 1.0 |
| • Residue content, % | 62.35 |
| Residue penetration, 0.1 mm | 101 |
| Residue ductility, cm | 103 |
| Solubility in trichloroethylene, % | 99.4 |

**Characteristics of Aggregates**

Two fractions of coarse aggregates derived from crushed river stone were used: one with aggregate diameter 5-10 mm and the other with crushed stone diameter 10-20 mm. River sand and stone dust obtained from stone crushed process were used as fine aggregate and filler, respectively. The aggregates used for material component in cold mixture were collected from Jeneberang river in Gowa. In this study, filler is defined as material passing a 0.075-l m sieve. The properties of coarse aggregates, fine aggregate and filler are shown in Table 3, Table 4 and Table 5, respectively.

**Table 3**. Properties of coarse aggregates

| **Properties** | **Crushed Stone** | |
|---|---|---|
| | **0.5–1 cm** | **1–2 cm** |
| Water absorption, % | 2.07 | 2.08 |
| Bulk specific gravity | 2.62 | 2.63 |
| Saturated surface dry specific gravity | 2.68 | 2.68 |
| Apparent specific gravity | 2.77 | 2.78 |
| Flakiness index, % | 20.10 | 9.38 |
| Abrasion aggregate, % | 25.72 | 24.36 |

**Table 4**. Properties of stone dust

| | |
|---|---|
| Water absorption, % | 2.79 |
| Sand equivalent, % | 89.66 |
| Bulk specific gravity | 2.45 |
| Saturated surface dry specific gravity | 2.51 |
| Apparent specific gravity | 2.63 |

**Table 5**. Properties of filler

| | |
|---|---|
| Water absorption, % | 2.28 |
| Sand equivalent, % | 69.57 |
| Bulk specific gravity | 2.56 |
| Saturated surface dry specific gravity | 2.66 |
| Apparent specific gravity | 2.76 |

**Combined Aggregate Gradation and Mixtures Design**

The aggregate gradation of mixtures was selected as the mid-point of the control limits used in the design of dense graded cold asphalt mixtures. The design limits and gradation used in this study are provided in Fig. 2. The combined aggregate gradation was kept for all mixture without BGA and with BGA. All mixtures were prepared in the laboratory. Table 6 shows the composition of mixtures without BGA.

Mixture without BGA and mixture with BGA were blended and compacted into the cylindrical mold with capacity of 1,200 gram and diameter of 101.6 mm. All specimens were compacted using the Marshall method of compaction at compactive effort of 50 blows per side. Mixing and compaction process were carried out in the laboratory at temperature room 27˚C. After compaction, samples were subjected to the following curing regime prior to conducting Marshal stabilty and ITS tests : 24 h ambient laboratory conditions in the sample mold, 24 h in a forced draft oven at 38˚C after demolding, and cooling at laboratory conditions.

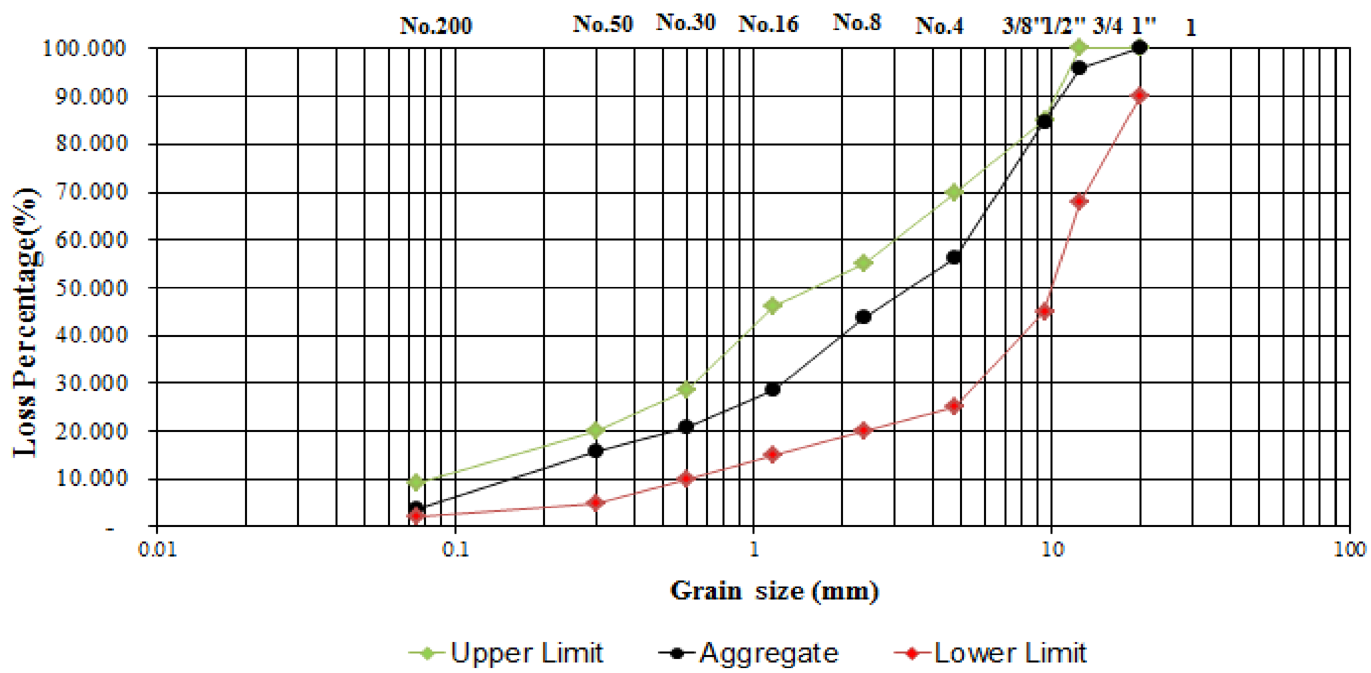


**Figure 2.** Combined aggregates gradation

**Table 6**. Composition of mixtures without BGA (for 1,200 grams)

| Mixture | CSS-1h | | | Coarse aggregates | | Stone Dust (Passing sieve no. #30) (gr) f | Filler (gr) g | Total (gr) a+b+c+d+e+f+g |
|---|---|---|---|---|---|---|---|---|
| Asphalt emulsion content (%) | Water Content (gr) a | Residual content (gr) b | Oil Content (gr) c | Crushed stone 1-2 cm (gr) d | Crushed stone 0.5-1 cm (gr) e | | | |
| 4.5 | 19.8 | 33.7 | 0.5 | 215.5 | 408.2 | 499.6 | 22.7 | 1200 |
| 5 | 22.0 | 37.4 | 0.6 | 215.5 | 408.2 | 493.6 | 22.7 | 1200 |
| 5.5 | 24.2 | 41.2 | 0.7 | 215.5 | 408.2 | 487.6 | 22.7 | 1200 |
| 5 | 26.4 | 44.9 | 0.7 | 215.5 | 408.2 | 481.6 | 22.7 | 1200 |
| 5.5 | 28.6 | 48.6 | 0.8 | 215.5 | 408.2 | 475.6 | 22.7 | 1200 |

### Marshall Stability Test and Indirect Tensile strength

The Marshall stability test was conducted on asphalt emulsion-mixture specimens according to SNI 06-2489-1991 [11]. Figure 3 show the Marshall stability test equipment.

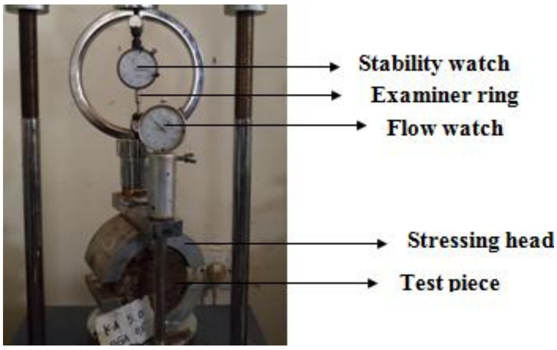


**Figure 3**. Marshall stability test equipment

ITS test was conducted on asphalt emulsion-mixture specimens according to ASTM D6931-12 [12]. Figure 4 show ITS equipment. Horizontal deformation of the specimen was measured by two LVDTs (linear variable displacement transducers) and used to calculate the strain due the tensile stress. The deformations of specimen and the load of UTM were monitored and recorded by a computerized data-logging system.

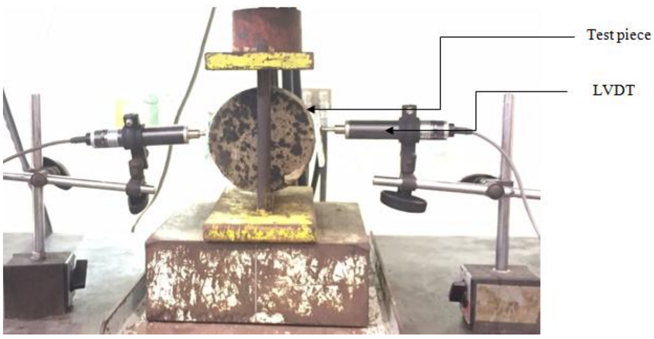


**Figure 4**. Indirect tensile strength equipment

## RESULTS AND DISCUSSION

### Stability of Cold Asphalt Mix AC-WC

***Relationship between asphalt emulsion content with stability***

Fig. 5 shows the relationship between asphalt emulsion content with stability. Three nominally identical companion specimens were cast for each asphalt emulsion mixture under investigation to ensure repeatability of results. Each value in the Table 7 is average of three similiar specicmens. After compaction, the stability of asphalt emulsion mixture can be established due to the contact between the petroleum bitumen droplet and mineral, led to induce the petroleum bitumen breakdown on the aggregate. Figure 3 indicates that the Marshall stability of asphalt emulsion mixtures increases initially, reaches a maximum value at 5.5% of asphalt emulsion content with corresponding with stability of 8.95 kN and then decreases with increasing of asphalt emulsion content. This result due to excessive asphalt emulsion coagulates together to form weak points inside the mixture and decrease the bond strength between petroleum bitumen and aggregate-filler.

**Table 7**. Relationship between asphalt emulsion content with stability

| Asphalt emulsion content (%) | 4.5 | 5 | 5.5 | 6 | 6.5 |
|---|---|---|---|---|---|
| Residual content (gr) | 34,02 | 37,80 | 41,58 | 45,36 | 49,14 |
| Stability (kN) | 4,18 | 6,04 | 8,95 | 5,13 | 3,72 |

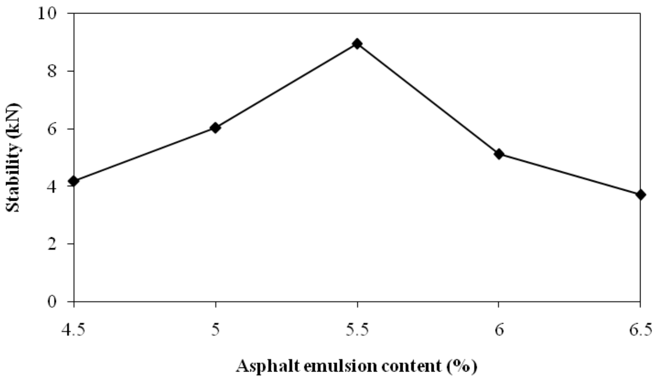


**Figure 5.** Relationship between asphalt emulsion content with stability

**Stability of mixture with BGA and without BGA**

Table 8 shows composition of mixtures with BGA and without BGA (for 1,200 grams) at optimum bitumen content of 5.5%. The improvement in stability with the change in BGA content can be seen by comparing mixture without BGA and mixtures with BGA in Fig. 6. It was observed 30–40% increase in stability by using 2.5-7.5% of BGA when compared with the mixture without BGA.

**Table 8**. Composition of mixtures with BGA and without BGA (for 1,200 grams)

| **Asphalt content (5.5%)** | | **Aggregate (gram)** | | | | | **Total** | **BGA content** |
|---|---|---|---|---|---|---|---|---|
| | | **Crushed stone 1-2 cm** | **Crushed stone 0.5-1 cm** | **Stone Dust (Passing sieve no. #30)** | **Filler** | | | |
| Emulsion asphalt (66gr)<br>Residue (63%) 41.58gr | BGA bitumen --- | 215.5 | 408.2 | 487.6 | Stone dust (22.7) | BGA minerals | 1200 gr | -- |
| Emulsion asphalt (59.1gr)<br>Residue (63%) 37.23gr | BGA bitumen (6.9gr) | 215.5 | 408.2 | 464.8 | Stone dust (22.7) | BGA minerals (23.1) | 1200 gr | (2.5%) 30 gr |
| Emulsion asphalt (52.2gr)<br>Residue (63%) 32.89gr | BGA bitumen (13.8gr) | 215.5 | 408.2 | 442.6 | Stone dust (22.7) | BGA minerals (46.2) | 1200 gr | (5% ) 60 gr |
| Emulsion asphalt (45.3gr) | BGA bitumen (20.7gr) | 215.5 | 408.2 | 464.8 | Stone dust (22.7) | BGA minerals (69.3) | 1200 gr | (7.5%) 90 gr |

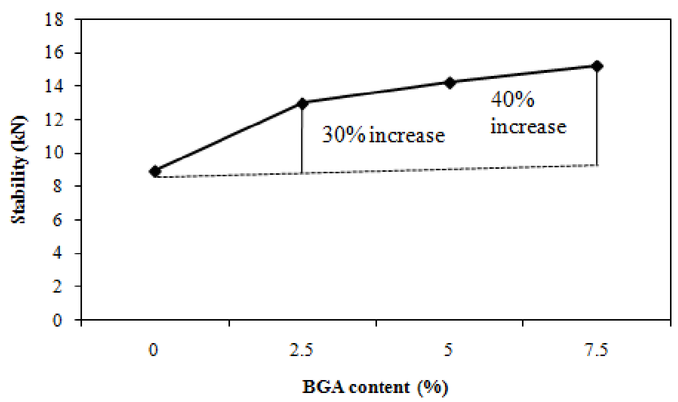


**Figure 6.** Relationship of BGA content with stability

**Relationship between BGA content with ITS**

Fig. 7 describes the relationship between BGA content with ITS test result. Visual observation on the specimens was carried out prior to ITS test. Visual observation result on compacted specimens shows that no pilling of bituminous material and filler bituminous at the lower end of the specimens. When asphalt emulsion containing petroleum bitumen and BGA are blended to produce a mixture, the chemical components of asphalt containing petroleum bitumen and BGA bitumen have a rearrangement, and a layer of membrane is formed to cover aggregate. The pores those left by the water of the asphalt emulsion mixture were filled by the presence of finer solid mineral (filler) of BGA. As a result as shown in Fig. 7, asphalt emulsion mixture containing BGA have the sufficient stability with resistance to deformation and the sufficient strength to withstand the tensile load.

ITS of mixture without BGA and mixture with 2.5%, 5% and 7.5% BGA were 0.0433 N/mm$^2$, 0.0844 N/mm$^2$, 0.0981 N/mm$^2$ and 0.1013 N/mm$^2$, respectively. ITS percentages increases were 48.69%, 55.86% and 57.25% with 2.5%, 5% and 7.5% BGA, respectively, compared with the corresponding value on the without BGA.

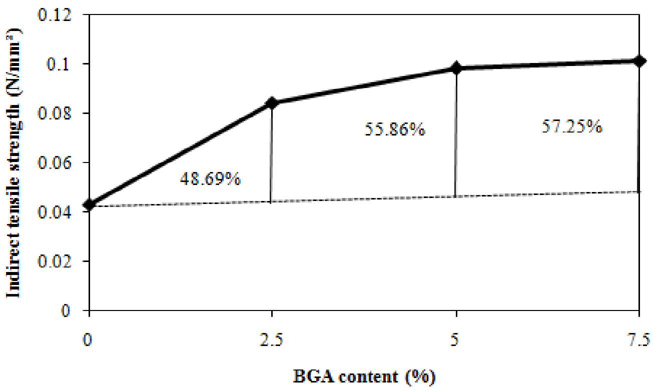


**Figure 7**. Relationship between BGA with IDT strength

**Stress-strain relationship in tensile**

A series of indirect tensile strength tests were performed on asphalt emulsion mixture with different BGA content. Indirect tensile strength test for each mixture is repeated three times in order to verify experimental. Stress-strain relationship for mixture in tensile is shown in Fig. 8 to Fig. 11.

Fig. 8 shows the tensile stress-strain relationship for mixture without BGA. The linear part of the stress strain curve between $0.3 \times 10^{-3}$ and $0.4 \times 10^{-3}$ strains reflect the elastic range of the mixture without BGA. The stress strain relationship shows that at the average peak stress of 0.0433 MPa resulting in strain value of $4.2 \times 10^{-3}$, $4.3 \times 10^{-3}$, and $3.5 \times 10^{-3}$ for three specimens, respectively.

Fig. 9 shows three repeated tensile stress–strain curves at 2.5% BGA content. The curves depict basically a linear response between $0.3 \times 10^{-3}$ and $0.7 \times 10^{-3}$ strains. They have similar peak tensile stress of 0.1009, 0.1021, and 0.1008 MPa, and almost overlap each other before the peak load is reached. The peak strain $4.6 \times 10^{-3}$, $4.2 \times 10^{-3}$, and $4.5 \times 10^{-3}$, and almost similar. It is indicated that the indirect strength test has good repeatability.

In Fig. 10, charts of tensile stress–strain relationships show the influences of 5% BGA content. The curves depict basically a linear response between 0.3% and 0.5% strains, then become non linear at higher strains before the peak indirect tensile stress are achieved between 0.5% and 5.5%.

The stress-strain curves for sample mixture with 7.5 BGA are given in Fig. 11. Stress and horizontal strains patterns were similar for all specimens. The specimens have a linear response up to $0.2 \times 10^{-3}$ strain and reach their ultimate strength at vertical strain of about $6.5 \times 10^{-3}$.

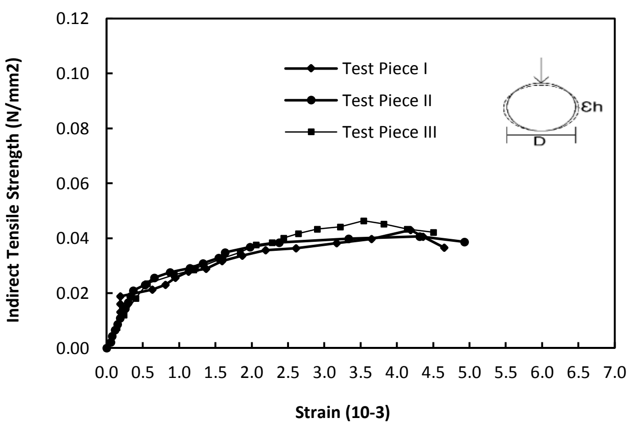


**Figure 8**. Indirect tensile strength-strain of asphalt emulsion mixture without BGA

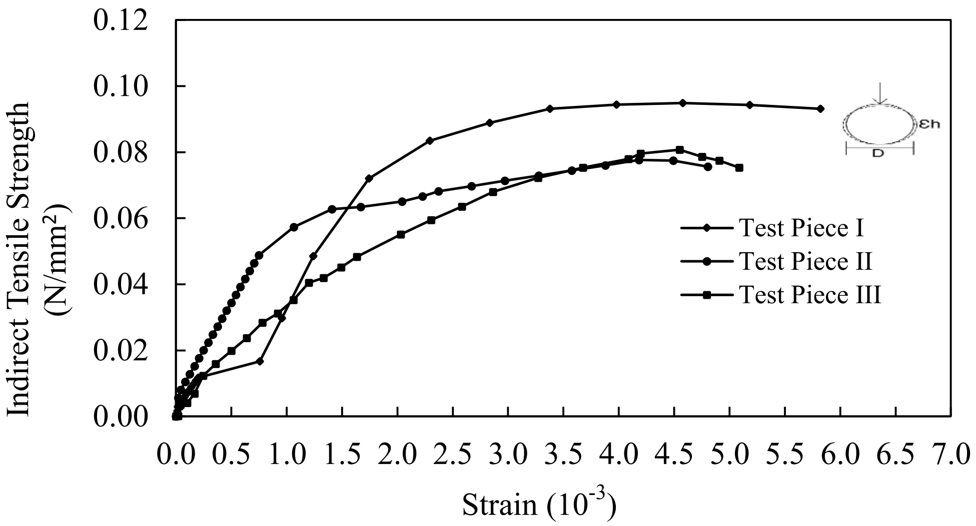


**Figure 9**. Indirect tensile strength-strain of asphalt emulsion mixture with 2,5% BGA

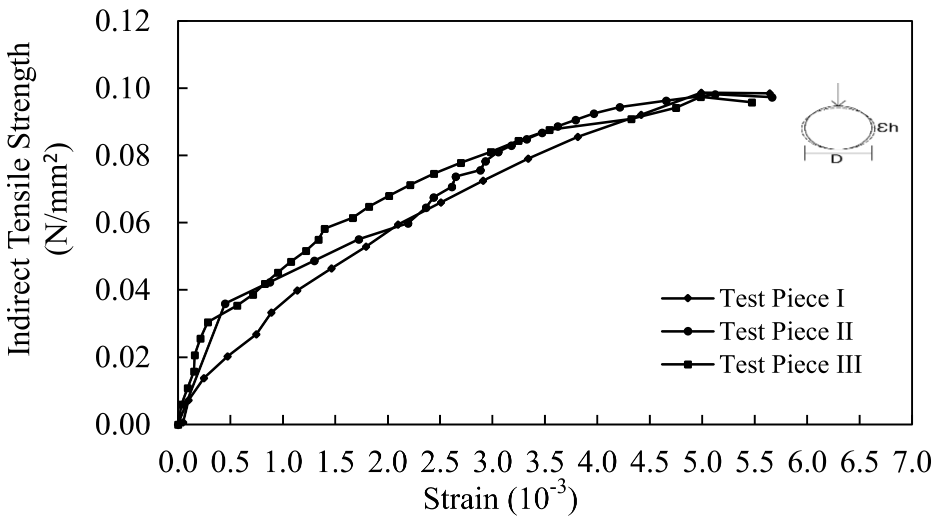


**Figure 10**. Indirect tensile strength-strain of asphalt emulsion mixture with 5% BGA

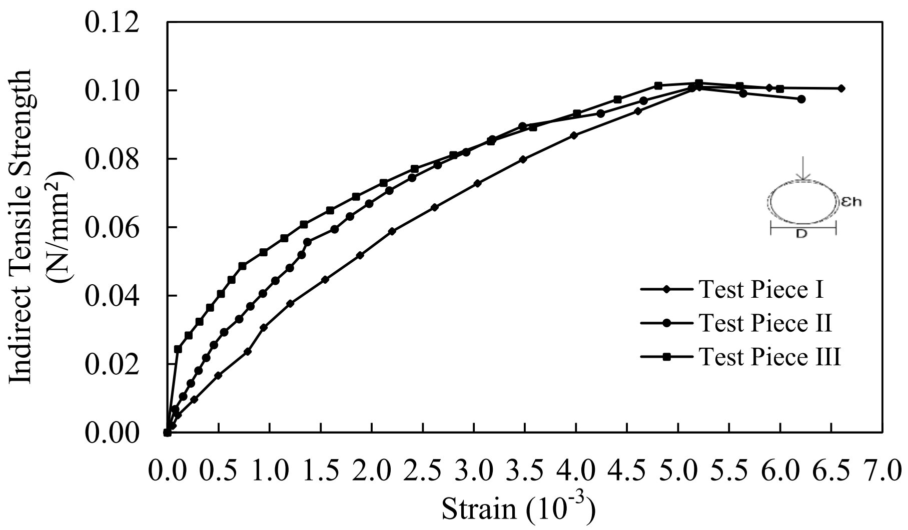


**Figure 11**. Indirect tensile strength-strain of asphalt emulsion mixture with 7.5% BGA

## CONCLUSIONS

1. The utilization of BGA with content from 2.5% to 7.5% increased the stability from 30% to 40% in comparison with the mixture without BGA.
2. The increase in indirect tensile strength was from 48.69% to 57.25% by the utilization of BGA with content from 2.5% to 7.5%.
3. Linear relationship of stress strain curve arose up to strain value approximately of $0.5 \times 10^{-3}$ and the strain value at the peak stress was from $4.5 \times 10^{-3}$ to $6.5 \times 10^{-3}$, regardless to the BGA content in the mixture.

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