Optimum amount of concrete objects of concrete asphalt layer using limestone aggregate

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Abstract. Concrete asphalt layer specimens are a mixture of coarse aggregate, fine aggregate, filler, and asphalt, which are crushed based on the number of collision plans. This study aims to determine the optimum number of collisions of concrete asphalt layer specimens using 100% coarse limestone aggregate against the Marshall Test. Marshall Tests produce Stability, Flow, and MQ values that are used to determine the age of the concrete asphalt layer plan. The stages of testing in this research were mixing the rough aggregate of limestone escaped sieve no. 3/4 - 8 mm or granular diameter between 0.5 cm - 2 cm, fine aggregate, filler, and asphalt. After mixing evenly and asphalt has covered all the aggregates, the mixture was inserted asphalt mold made of brass with a diameter of 100 mm height 65 mm. The next process is a compaction of the test specimen with five variations of collisions (50, 75, 100, 125, 150). After the test object is compacted, then a Marshall test is performed to find out the value of Stability, Flow, and MQ. The results of this study indicate that the optimum number of collisions is 100 times. This can be seen from the value of Stability: 1412 kg, Flow: 4.02 mm, and MQ: 351.2 kg/mm.

1. Introduction
In the implementation of road pavement, a mixture of concrete asphalt layers is very influential on the characteristics of the planned asphalt layer. Asphalt concrete mixture for pavement in the manufacture of research specimens was designed using the Marshall method. In the process of making test specimens in the laboratory, collisions of 75 collisions were usually carried out. Asphalt concrete test specimens are a mixture of coarse aggregate, fine aggregate, filler, and asphalt, which are crushed based on the number of collision plans. High traffic intensity of commercial vehicles, truck overloads and significant variations in daily and seasonal temperatures have been responsible for the initial development of distress symptoms, such as raveling, undulations, rutting, cracking, bleeding, shoving, potholing from the asphalt surface [1].

Over the past decade, an understanding of the structure and dynamics of complex networks and their mutual interactions has made great progress. This particular type of network is a transportation system, where the direct flow of individual transportation units is often limited to spatially separated substrates consisting of interconnected tracks. Merging, perversion, and intersection between these tracks can be considered as a network node and the physical connection as an appropriate link. The resulting property graph determines together with the link capacity and actual temporal-spatial demand pattern, the efficiency of transportation in the system. In modern society, the optimal performance of the transportation system is significant for daily life. As a result, the evolution of structure and time from such networks often results
from careful planning processes [2]. One effort that can be done is to create a good quality land transportation route so that it can provide optimal services in the country’s economic flows [3], [4]. It is expected that the implementation of the road pavement works by procedures so that maximum results are obtained. However, in reality, what happened, on the contrary, many ignored the importance of the collision process in the new pavement layers. Proper collision improves the structural quality of the Road, resulting in contact points between particles, which supports the better distribution of forces. The structure formation for asphalt mixture depends on the collision method and the level of impact determined. Meanwhile, the way the asphalt mixture is compacted in the field significantly affects the level of impact, which is related to the quality of asphalt pavement construction.

Therefore, it is necessary to understand the integration of asphalt mixture for asphalt mixture design and asphalt pavement construction [5]. High-quality asphalt mixture compactness is of critical importance for the design and construction of high-performance proper asphalt pavement. Compared to field collision, laboratory collision can provide a more controlled environment of mental factors, including temperature and humidity, energy collision and less material consumption. Moreover, in a collision laboratory, it can reduce the previous loading for some tests by eliminating the removal of the drill core from intact asphalt pavement [6]. The compact mix of asphalt air holes is sufficient to prevent deformation and exudation, at the same time allowing the interaction of locking components [7]. Because the collision process is also one of the factors of the feasibility of road life. In a collision, what needs to be considered is how much the level of collision is to fit, so that the pavement layer is durable to the age of the plan. If the collision process is not right then what happens is that the pavement layer is easily destroyed, on the contrary, if the collision process exceeds the number of collisions, causing coarse aggregate with limestone contained in the concrete asphalt layer specimens will be destroyed thereby reducing the value of stability on the road. Limestone aggregates are collected locally. The effect of Marshall Design parameter rules (number of collisions and collision temperatures) at high and low temperatures stabilities and water stability of printed test specimens were investigated. The impacting effect of the porous asphalt mixture is evaluated as the theoretical basis for the technology of lime porous asphalt pavement collision technology [8]. The Marshall test is an empirical test in which cylindrical compacted specimens, diameter 100 mm with a height of about 63.5 mm, are immersed in water at 60 C for 30-40 minutes and then loaded onto a curved steel plate along the diameter with a constant compression rate of 51 mm/min. The Marshall stability value (in kN) is the maximum force recorded during compression while the flow (in mm) is the deformation recorded at the maximum force [9].

So from this background, in this study, an attempt was made to analyze the optimum level of pavement coating on the value of asphalt stability in the use of limestone aggregate. The purpose of this study was to determine the optimal level of collision in the concrete asphalt layer specimens with the use of 100% of the limestone aggregate from the Marshall test, so that concrete asphalt layer specimen was able to reach the optimal plan life.

2. Literature Review
The composition of the test specimens in this study used limestone aggregates, bitumen emulsions, Portland cement, and bitumen. The raw material for capsules and calcium-alginate particles consists of cationic asphalt emulsion K1-60, 60% asphalt content, with a 1.03 g/cm3 collision, sodium alginate (C6H7O6Na) and, calcium chloride (CaCl2) in granular pellets and purity of 93%. CEM I 52.5 N Portland cement is used as a substitute for fillers to improve CMC properties. Finally, virgin bitumen penetration grade AC 60-70 is used to produce hot mix asphalt [10].
2.1. Asphalt

Asphalt is a plastic material that has a sizeable adhesive value so that it becomes the primary material in the manufacture of road pavement layers. Asphalt / Bitumen has thermoplastic properties in which if there is an increase in temperature, the shape of the asphalt will become liquid, and vice versa, if there is a decrease in temperature, the asphalt becomes hard [11]. Asphalt binder types AC60-70, according to DOH specifications, were chosen for this study because they are the most commonly used asphalt binder in Indonesia for standard HMA blends, along with high-quality HMA blends from AC60-70 and Polymer Modified Asphalt (PMA), respectively -mind. Samples of this type of asphalt binder are collected from asphalt refining plants in Indonesia.

An initial evaluation of the asphalt samples collected was carried out to ensure that their significant properties comply with DOH specifications for new binders and binders that were processed after Thin Film Oven (TFO) [12]. Loose heat mix asphalt is sampled directly from production transport vehicles. Before laboratory compaction, the mixture is placed in an oven until the compaction temperature reaches 135°C. Twelve specimens were compacted according to the AASHTO TP4-93 procedure using SGC (Model 4140, Troxler Corp, Research Triangle Park, N.C.). The diameter of the laboratory compacted specimen is 150 mm, and the height varies in the range of 100-120 mm, depending on the level of compaction [13]. In this study focused on the amount of impact, the asphalt content used is only at 5%. For maximum results, in several asphalt test categories, including flash point and soft test, ductility test.

2.2. Aggregate

Aggregates play an essential role in the performance of asphalt mixtures. Aggregates form approximately 88% to 96% by weight and volume of the total mix, the effect of aggregates on bitumen characteristics; the combination is significant. One of the main aspects of the sum that affects the stability and nature of mixed work is its gradation. The aggregates used are classified as coarse and fine aggregates based on their size [14].

- (i) Coarse aggregates: Aggregates maintained taken as coarse aggregates on a 2.36 mm sieve.
- (ii) Fine aggregate: Aggregate that passes through the 2.36 mm sieve and at 0.075 mm or 75 microns maintained. The filter is taken as fine aggregate.
- (iii) Mineral Filler: Semen is used as a mineral filler in this study, which fills the void between aggregate fines, strengthens bitumen [1].

2.3. Limestone

Historically limestone and relatively metamorphic marble have been used as building materials on a global scale for aesthetic and practical reasons, with examples ranging from the Giza pyramid, Nummulite limestone with Tura limestone sheath, Diocletian Palace in Split built from Brač limestone to Gothic European Cathedral. Aside from being a source of building stones, this stone is also a valuable source of crushed stone aggregates suitable for construction fillers and underground road materials. As a building stone in ancient limestone, it can be easily done even with stone tools, with evidence of carvings and excavations as building stones as early as the Naqada I culture in Egypt pre-dynastic Egypt, 3900-3500 BC. Furthermore, with Belas Knap, a long barrow booth in Gloucestershire, England, being of the same vintage and using limestone thresholds. The decorative limestone carvings that were worked on have been discovered and dated as early as 32,000 BC, specifically Venus Willendorf, Germany [15].

In porous asphalt mixtures, aggregates must be uniform, clean, and dry. Important properties for coarse aggregate include the contents of elongated and scaly particles, crushed stone values, and loss of Los Angeles abrasion. In this study, calculating the cost of road materials (the price of coral bought from other places is 300 thousand/cubic, while the price of locally produced
limestone is 175 thousand/cubic) and the limestone output of a large definite region, limestone is thus chosen as porous coarse aggregate asphalt mixtures in this study, provided all selected limestone properties meet relevant technical requirements [8]. Limestone is a sedimentary rock which is mainly composed of calcium carbonate (CaCO3) in the form of calcite minerals and is one of the materials for development that has been widely used by humans [16].

The mineralogical composition of limestone was obtained by XRD analysis. The main component proved to be calcite for both samples, although this did not preclude the possibility of a small amount (<5%) of the CaCO3 polymorphs and other dolomites [17]. For a long time, a mixture of limestone has been widely used as a building material. Limestone contains 98.9% calcium carbonate (CaCO3) and 0.95% magnesium carbonate (MgCO3). The analysis was carried out in limestone, lime, and cut limestone samples using the following analytical procedures.

(i) X-ray diffraction (XRD) analysis of finely ground limestone samples for the identification of the crystalline compounds presented. Analyzes were performed with Siemens D-5000 (with graphite crystal monochromator and Cu anti code). The diffraction interval is between 2° − 5° and 20° − 50° in steps of 0.02°.

(ii) Transmitted light microscopy (Nikon, Optiphot-Pol) is carried out on thin sections of polished limestone to identify the texture, shape, and size of grains.

(iii) Calcimetry (volumetric gas method, Dietrich Fruhking) has been carried out in limestone powder to determine CO2 content.

(iv) Atomic absorption spectroscopy (AAS, Perkin Elmer 3300) is used on limestone to determine the percentage of ions, calcium (Ca2 +), and magnesium (Mg2 +).

(v) Simultaneous thermal and thermogravimetric analysis (DTA / TG) is carried out to determine the various compounds presented quantitatively and qualitatively. The analysis was carried out in limestone and lime putty samples in the static air atmosphere at a temperature range of 30 ± 1000°C and a gradient of 10° C/min (Netzsch 409 EP DTA/TG).

(vi) Mercury intrusion porosimetry (Fisons, Porosimeter 2000) was used to measure the microstructure characteristics of lime, lime, and solid lime putty. Estimates of total porosity, specific surface area, mean pore radius, total cumulative volume, and real density have been achieved.

(vii) Nitrogen adsorption was carried out on lime and lime to evaluate specific surface area values with physical sorption isotherm data according to the Brunauer ± Emmet ± Teller (BET) method. The benefits above are compared with those obtained from mercury intrusion axisymmetry [17].

3. Methodology
3.1. Aggregate Mixing
The Aggregate framework is separated into two fractions: one containing coarse aggregate and sand and the other containing sand with fine elements and adding fillers. Only coarse aggregate and sand without drying and heating; they are heated to moderate temperatures (usually 150° C). They store calorie energy, which will then be transferred to the cutting element of the mixture. The asphalt binder is heated to the recommended temperature (between 140° C and 180° C, depending on its level and nature). Specially formulated additives are added to the asphalt binder to enable and enhance wet element foam and coating. This additive allows, in contact between the water and the warm bitumen, to regulate expansion and prevent stripping of water from the bitumen that has been installed in the coarse aggregate. Coarse aggregate is hot coated with all the last mix asphalt. Thick, hot asphalt films adhere firmly around coarse aggregates, and adhere well and are well distributed around grains and sand carried to the
same temperature. Addition of wet sand at room temperature triggers complex reactions which include:

(i) Asphalt binder expanded and foaming.
(ii) Sand grains are encapsulated by foamy bitumen.
(iii) Cold sand is heated through contact.
(iv) Excess water is recondensed and distributed evenly in the mixture.
(v) The homogeneous mixture is obtained.
(vi) Final mixed temperature balance is reached below 100° C. [18]

3.2. Collision Test

In making test specimens, collision testing is necessary. Collision is defined as the level of variation in volume and stability during the collision process and the duration of the service path. Asphalt mixtures that show good impact can be easily compressed with volume design requirements maintain a certain degree of stability, have excellent resistance to deformation, and show good performance during road use [19]. The collision can produce cylindrical asphalt samples with a diameter of 100 mm or 150 mm (other widths are possible with some adjustments to the settings) [6]. So when the test object is tested Marshall can get maximum results. In the process of collision, the level of collision must be appropriate so that the pavement layer has stability in the pavement layer. If the level of collision is less then the pavement layer is easily destroyed due to lack of level of a collision, and vice versa, if the level of collision is high, then it results in the destruction of the aggregate in the concrete layer mixture. Before the collision process is carried out, the first step that must be taken is to mix the rough limestone aggregate with the conditions of passing gradation no. 3/4 - 8 mm or with a diameter between 0.5 cm - 2 cm, fine aggregate, filler and asphalt. The second step after mixing well and it is confirmed that the asphalt covers all the aggregates and then the mixture is put into asphalt molds made of brass with a diameter of 100 mm. the last step is the collision test, where the collision test is carried out as much as 75 collisions per field [20]. In this test, we tried by comparing the number of collisions with the collision variations, namely 50, 75, 100, 125, 150 times.

3.3. Asphalt Testing Using the Marshall Method

This test is carried out according to ASTM D1075 specifications. Standard Marshall specimens of 100mm in diameter and 63.5 in height were prepared. Marshall stability was determined using standard procedures, after conditioning a set of samples at 60° C for 30 - 40 minutes. A collection of specimens stored for conditioning in a water bath is maintained at 60° C for 24 hours, and after that, it is tested for Marshall Stability values [20–23]. The test method is carried out, as follows:

(i) The time needed from the moment the specimen is removed from the soaking tub or oven until the maximum load is reached must not exceed 30 seconds. Soak the samples in a water bath for 30 - 40 minutes with a constant temperature of 60°C (±1°C) for specimens using stable asphalt, for specimens using liquid asphalt put the specimens in the oven for a minimum of 2 hours with a fixed temperature of 25°C (±1°C).

(ii) Remove the test specimen from the sink or the stove and place it in the lower segment of the pressure head.

(iii) Mount the upper part above the test piece, and place the whole in the testing machine.

(iv) Put the flow meter watch on its position above one of the guide bars and set the location of the pointer at zero, while the sleeve of the clock is held firmly against the top segment of the pressure head.
(v) Before loading, the pressure head and the test object are raised so that they touch the base of the test ring.

(vi) Set the watch needle to zero position;

(vii) Give loading to the test object with a fixed speed of about 50 mm per minute until the maximum loading is reached or the loading decreases as indicated by the pressure watch needle and note the maximum loading (stability) achieved, for the test object whose thickness is not as large as 63.5 mm.

(viii) Record the flow value indicated by the flow gauge watch when the maximum load is reached [24].

| Table 1: Limestone Aggregate Test Results |
|------------------------------------------|
| No | Check | Results | Specification |
|----|-------|---------|---------------|
|    |       | Test    | Min | Max | Unit |
| 1  | Water Absorption | 2.018 | - | 3 | % |
|    | Limestone 0.5-1 cm | 2.018 | - | 3 | % |
|    | Limestone 1-2 cm | 2.018 | - | 3 | % |
| 2  | Specific gravity | 2.645 | 2.5 | - | - |
|    | Limestone 0.5-1 cm | 2.56 | 2.5 | - | - |
|    | Bulk Specific Gravity | 2.654 | 2.5 | - | - |
|    | SSD Specific Gravity | 2.641 | 2.5 | - | - |
|    | Pseudo Specific Gravity | 2.584 | 2.5 | - | - |
|    | Limestone 1-2 cm | 2.583 | 2.5 | - | - |
| 3  | Leaning Index | 0.4 | - | 25 | % |
|    | Limestone 0.5-1 cm | 0.6 | - | 25 | % |
| 4  | Aggregate Wear | 24.45 | - | 40 | % |
|    | Limestone 0.5-1 cm | 22.35 | - | 40 | % |
| 5  | Aggregate Stickiness | >96 | - | >95 | % |
|    | Limestone 0.5-1 cm | >96 | - | >95 | % |
| 6  | Aggregate Strength | 19 | 10 | 30 | % |
|    | Limestone 0.5-1 cm | 16 | 10 | 30 | % |

4. Results and Discussion

Testing to determine bulk density, saturation dry surface density, the apparent density of coarse aggregate, and absorption rate of coarse aggregate. Calculation of specific gravity and absorption of coarse aggregate is given as follows:

(i) Bulk specific gravity, $\frac{B_k}{B_{ly-Ba}}$

(ii) Saturated dry-surface specific gravity, $\frac{B_i}{B_{ly-Ba}}$
(iii) Pseudo specific gravity (apparent specific gravity), \( \frac{B_k}{B_k - B_a} \)

(iv) Absorption, \( \frac{B_j - B_k}{B_k} \times 100\% \)

Information: \( B_k \) the weight of oven-dry test specimen, in grams. \( B_j \) the importance of the saturated surface dry specimen, in grams. \( B_a \) the pressure of dry surface saturated test specimen in water, in grams [25]. From the test results obtained by the results of the limestone aggregate test. The results can be seen in Table 1.

The next step is testing the characteristics of asphalt. Where the asphalt characteristics testing includes: specific gravity test, asphalt penetration rate test, flash point, and fuel test, and asphalt viscosity and aggregate test. The results of this test are written in Table 2.

| Table 2: Asphalt Test Penetration 60/70 |
|----------------------------------------|
| test | the results | criteria |
|----------------------------------------|
| penetration rate test | losing weight | pen 60/70 |
| | 61.39 | |
| | without losing weight | |
| | 68.36 | |
| asphalt specific gravity test | 1.013 | 1.01-1.04 |
| flashpoint and burn test | On: 295° | - |
| | burn 310° | |
| Viscosity rate | 96% | ≥ 95% |

After getting the results of aggregate and asphalt testing, then Marshall test characteristics. For the Marshall test, specimens were made according to Marshall standards. Four replications of the specimens for each group (101.6 mm diameter and 63.5 ± 1.3 mm height) were produced with 75 blows of compaction energy per side before measuring Marshall stability (MS) [26]. The test method is carried out, as follows: The time needed from the moment the specimen is removed from the soaking tub or oven until the maximum load is reached must not exceed 30 seconds. In this Marshall test, only stability, flow, and MQ values are tested because the volumetric values of asphalt (VIM, VMA, VFB) are considered to be fulfilling.

| Table 3: The average collision variation results |
|-----------------------------------------------|
| compacting variations | Stability | Flow | MQ |
|------------------------|-----------|------|----|
|                       | kg        | mm   | kg/mm |
| 50 collision           | 765       | 1.15 | 665.2 |
| 75 collision           | 1273      | 3.71 | 343.1 |
| 100 collision          | 1412      | 4.02 | 351.2 |
| 125 collision          | 1205      | 2.89 | 417.0 |
| 150 collision          | 1088      | 2.09 | 520.6 |
| provisions             | >800 kg   | 2-5 mm | 250-400 kg/mm |

The conclusion from the table above results in the value of flow stability and also MQ increase with the number of collisions performed. The highest value occurred at the collision of 100. At collision 100, it was seen that both in terms of stability, flow, and MQ were quite good and met the standards of highways. However, the higher the number of collisions, namely, the collision of 150 shows that there was a drastic decrease from the number of collisions of 100. In the collision
of 150, the stability value was 1088 kg, the flow value was 2.09 mm, the MQ of 520.6 kg/mm was far compared to the collision of 100 ie at a stability value of 1412 kg, flow 4.02 mm, and MQ of 351.2 kg/mm. This shows that the addition of the amount of impact also affects the results of the asphalt mixture with the use of these limestone aggregates.

4.1. Effect of Collision Against Stability
The graph on Figure 1 below presents the results of the stability of the pavement layers with the impact of impact. The value of the collision of 50 does not reach a conclusion set by the DGH, which must be more than 800 kg, which is only 765 kg. Whereas the collision of 75, 100, 125, and 150 fulfills the specifications of the Bina Marga, namely with the values of each 1273 kg, 1412 kg, 1205 kg, 1088 kg. However, even though it meets the specifications of the Bina Marga but it is seen that from the collision of 100, 125, and 150 there is a decrease in the value of stability, this shows that the effect of the addition of collision makes the value of stability in the mixture with coarse aggregate of limestone change.

![Figure 1: Stability value of the number collisions](image)

4.2. Effect of Collision Against Flow
The graph on Figure 2 below provides a conclusion that the value of Flow reaches its peak at 100 collisions. At the collision value of 100, the results achieved are 4.02 mm (included in the specifications of DGH). It can also be seen in the flow chart that the lowest point curvature occurs in collisions of 50 and 150 with values of 1.15 mm and 2.09 mm, respectively. This proves that the value of flow will reach its maximum at a certain point of impact.

4.3. Number of Collisions Against MQ
Figure 3 shows that the MQ value is influenced by the stability value divided by the flow value. Thus the MQ value is the stability level of a road pavement layer so that the MQ value is between 250-400 kg/mm. The value is following the specifications of DGH. The graph also shows that fulfilling these criteria is the collision of 75 and 100, where the values are 343.1 kg/mm and 351.2 kg/mm, respectively.
5. Conclusion and Suggestions
This study shows that concrete asphalt layer specimens using limestones aggregate produce the highest stability, Flow, and MQ values at collisions 100 (Stability: 1412Kg, Flow: 4.02mm dan MQ: 351.2Kg/mm).

This research resulted in the latest innovation in the use of limestone coarse aggregate material for concrete asphalt mixture, mainly determining the optimum number of piles of compaction of the specimens. This research can be further refined by using variations in the amount of asphalt.
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