# CHAPTER IV
# RESULT AND DISCUSSION

## 4.1 Result of Research

### 4.1.1 Sand Testing Result

1) Sand Sieve Analysis

Table 4.1 Sand Sieve Analysis

| Sieve | | Retained on the sieve | | | | %Cumulative | |
|---|---|---|---|---|---|---|---|
| No | mm | Tray Weight (gr) | Tray + sand (gr) | Retained Sand (W1) (gr) | % Retained Sand | Retained (A) | Pass (100 -A) |
| 3/8 " | 9.5 | 472 | 1472 | 0 | 0.00 | 0.00 | 100 |
| No. 4 | 4.75 | 472 | 510 | 38 | 3.80 | 3.80 | 96.2 |
| No. 8 | 2.36 | 332 | 389 | 57 | 5.70 | 9.50 | 90.5 |
| No. 16 | 1.18 | 306 | 459 | 153 | 15.30 | 24.80 | 75.2 |
| No. 30 | 0.60 | 350 | 581 | 231 | 23.10 | 47.90 | 52.1 |
| No. 50 | 0.30 | 293 | 470 | 177 | 17.70 | 65.60 | 34.4 |
| No. 100 | 0.15 | 284 | 506 | 222 | 22.20 | 87.80 | 12.2 |
| Pan | 0 | 372 | 492 | 120 | | | |
| Amount | | | | 998 | | 239.40 | |
| Fineness Modulus | | ∑% Retained Cumulative/100 | | | | 2.394 | |

(*Source: Author, 2024*)

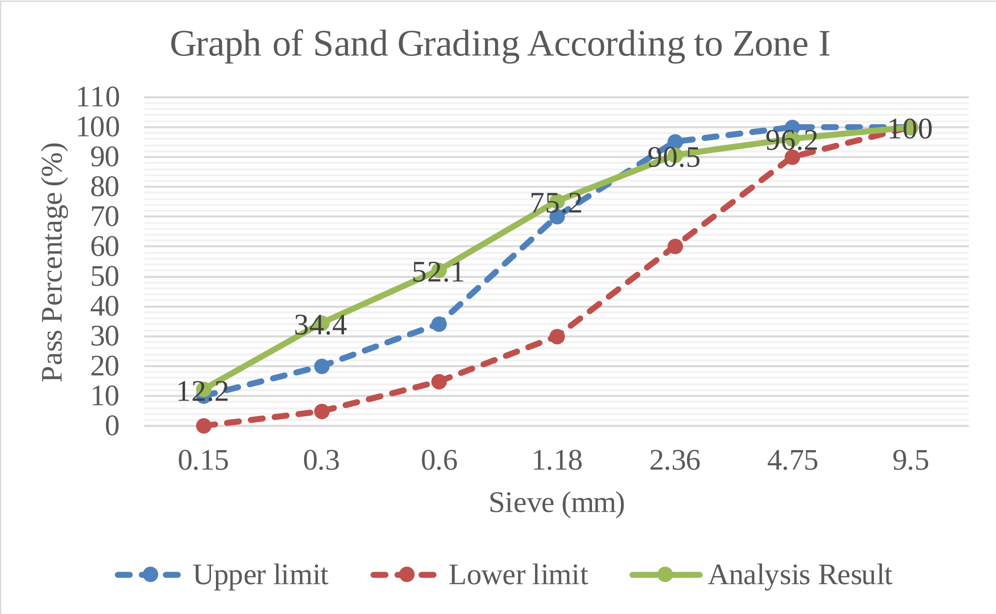



Figure 4.1 Sand grading graph of zone 1
(*Source: Author, 2024*)

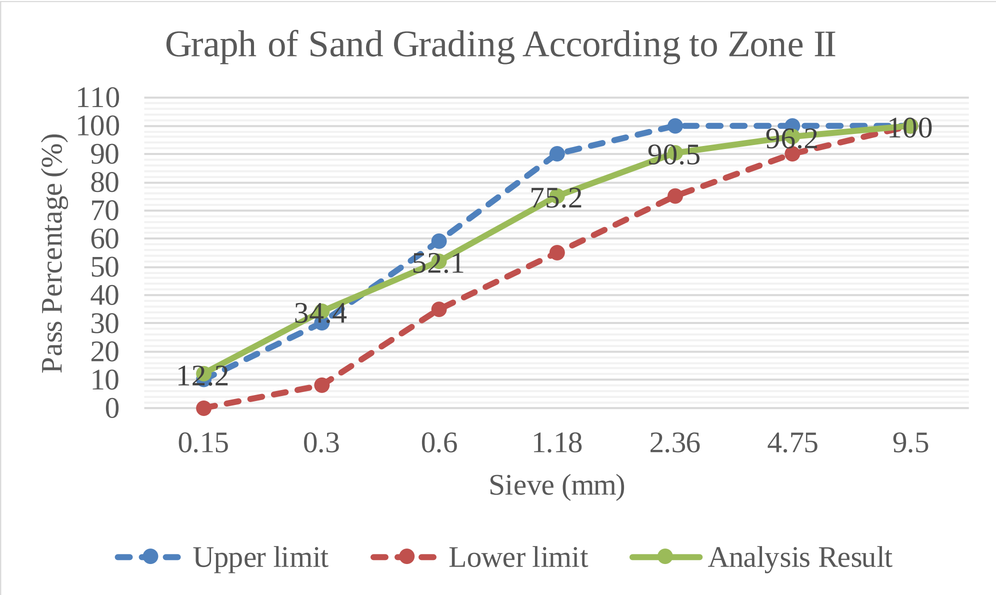



Figure 4.2 Sand grading graph of zone 2
(*Source: Author, 2024*)

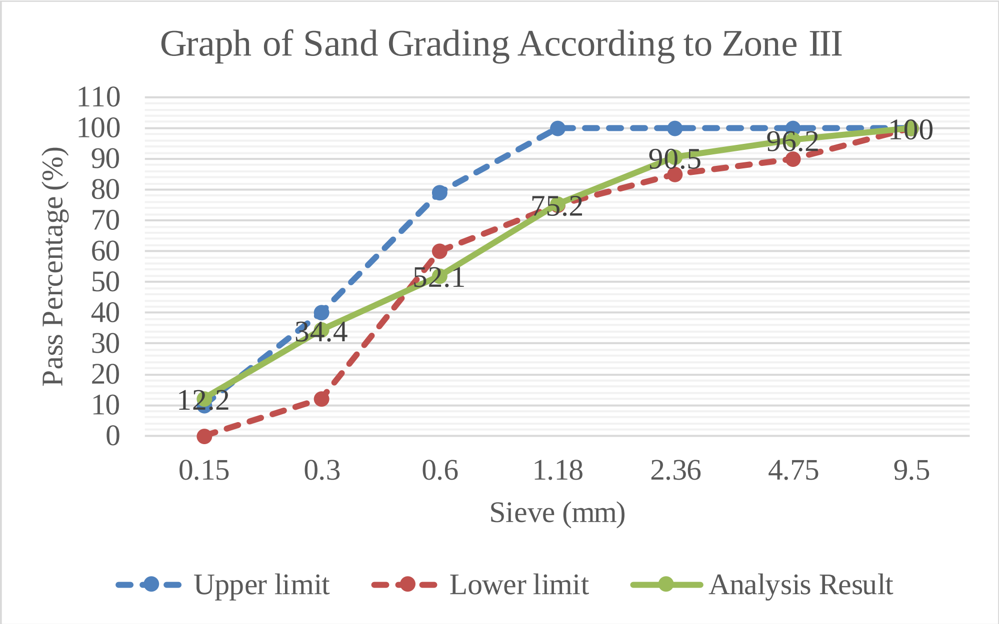



Figure 4.3 Sand grading graph of zone 3

(*Source: Author, 2024*)

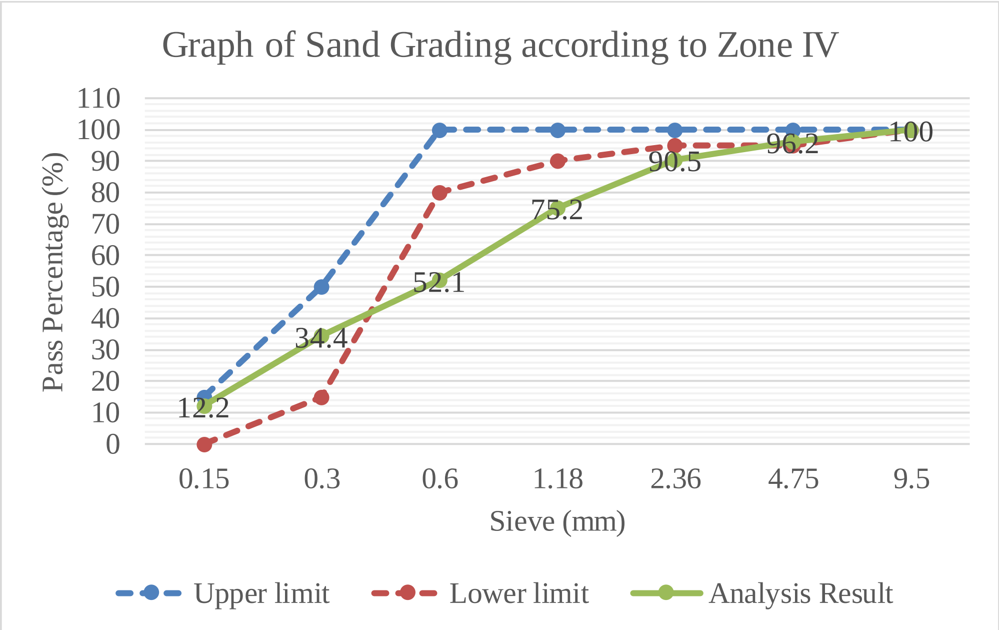



Figure 4.4 Sand grading graph of zone 4

(*Source: Author, 2024*)

From the results of the sand sieve analysis, it was concluded that the sand used in the study was in zone 2.

2) Volume Weight of Sand Analysis

Table 4.2 Sand volume weight test result data

| Test | Without Stabbed | | With Stabbed | |
|---|---|---|---|---|
| | 1 | 2 | 1 | 2 |
| Weight of Cylinder | 3728 | 3728 | 3728 | 3728 |
| D/H Cylinder (cm) | 15.5/15 | 15.5/15 | 15.5/15 | 15.5/15 |
| Volume of Cylinder ($cm^3$) | 2739 | 2739 | 2739 | 2739 |
| Weight of Cylinder + Sand | 8521 | 8536 | 8784 | 8806 |
| Sand | 4793 | 4808 | 5056 | 5078 |
| Sand / Volume ($gr/cm^3$) | 1.750 | 1.755 | 1.846 | 1.854 |
| Mean | 1.753 | | 1.850 | |

(*Source: Author, 2024*)

Calculation Without stabbed:

$$\text{Volume Weight of Sand} = \frac{(\text{Cylinder Weight+ Sand}) - (\text{Cylinder Weight})}{\text{Volume Cilinder}}$$

$$\text{Volume Weight of Sand 1} = \frac{(8521) - (3728)}{2739} = 1.750 \text{ g/cm}^3$$

$$\text{Volume Weight of Sand 2} = \frac{(8536) - (3728)}{2739} = 1.765 \text{ g/cm}^3$$

Calculation With stabbed:

$$\text{Volume Weight of Sand} = \frac{(\text{Cylinder Weight+ Sand}) - (\text{Cylinder Weight})}{\text{Volume Cilinder}}$$

$$\text{Volume Weight of Sand 1} = \frac{(8784) - (3728)}{2739} = 1.856 \text{ g/cm}^3$$

$$\text{Volume Weight of Sand 2} = \frac{(8806) - (3728)}{2739} = 1.854 \text{ g/cm}^3$$

3) Sand Moisture Analysis

Table 4.3 Sand moisture analysis result

| Test No. | | 1 | 2 |
|---|---|---|---|
| Weight of Tray | gram | 546 | 148 |
| Tray + Sand | gram | 1046 | 648 |
| Sand Weight (W1) | gram | 500 | 500 |
| Tray Weight + Sand Oven | gram | 1023 | 625 |
| Sand Oven Weight (W2) | gram | 477 | 477 |
| Sand Moisture (%) | % | 4.82 | 4.82 |
| Mean (%) | % | 4.82 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Sand Moisture} = \frac{\text{Weight of Sand - Weight of Oven Sand}}{\text{Weight of Oven Sand}}$$

$$\text{Sand Moisture 1} = \frac{500 - 477}{477} \times 100\ \% = 4.82\ \%$$

$$\text{Sand Moisture 2} = \frac{500 - 477}{477} \times 100\ \% = 4.82\ \%$$

4) Sand Absorption Analysis

Table 4.4 Result of sand absorption analysis

| Test No. | 1 | 2 |
|---|---|---|
| Weight of Tray | 35 | 34 |
| Tray + Sand SSD | 535 | 534 |
| Weight of Sand SSD (W1) | 500 | 500 |
| Container + Sand Oven | 531 | 530 |
| Weight of Sand Oven (W2) | 496 | 496 |
| Absorption (%) | 0.81 | 0.81 |
| Mean (%) | 0.81 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Sand Absorption} = \frac{\text{Sand SSD Weight - Sand Oven Weight}}{\text{Sand Oven Weight}}$$

$$\text{Sand Absorption 1} = \frac{500 - 496}{496} \times 100\ \% = 0.81\ \%$$

$$\text{Sand Absorption 2} = \frac{500 - 496}{496} \times 100\,\% = 0.81\ \%$$

5) Sand Relative Density Analysis

Table 4.5 Result of sand relative density Analysis

| Test No. | 1 | 2 |
|---|---|---|
| Pycnometer Weight (W1) | 373 | 381 |
| Weight of Sand SSD (W2) | 500 | 500 |
| Sand SSD + Pycnometer (W3) | 873 | 881 |
| Pycnometer + Sand SSD + Water (W4) | 1684 | 1693 |
| Pycnometer + Water (W5) | 1368 | 1376 |
| Surface Dry Saturated Relative Density | 2.72 | 2.73 |
| Mean | 2.72 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Sand Relative Density} = \frac{W3 - W1}{(W5+W2) - W4}$$

$$\text{Sand Relative Density 1} = \frac{873 - 373}{(1368 + 500) - 1684} = 2.72\ \text{Kg/L}$$

$$\text{Sand Relative Density 2} = \frac{881 - 381}{(1376 + 500) - 1693} = 2.73\ \text{Kg/L}$$

6) Bulking of Sand

Table 4.6 Result data of sand bulking

| Test No. | 1 | 2 |
|---|---|---|
| Sand Volume 1 (V1) | 375 | 375 |
| Sand Volume in Water (V2) | 300 | 315 |
| Bulking (%) | 25 | 19 |
| Mean | 22 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Bulking of Sand} = \frac{V1 - V2}{V2} \times 100\%$$

$$\text{Bulking of Sand 1} = \frac{375 - 300}{300} \times 100\% = 25\%$$

$$\text{Bulking of Sand 2} = \frac{375 - 315}{315} \times 100\% = 19\%$$

7) Analysis of Sand Cleanliness Against Mud by Wet Method

Table 4.7 Analysis of Sand Cleanliness Against Mud by Wet Method

| Test No. | 1 | 2 |
|---|---|---|
| Height of Mud (mm) (H1) | 1 | 1 |
| Height of Sand (mm) (H2) | 124 | 117 |
| Mud Content % | 0.81 | 0.85 |
| Mean | 0.83 | |

*(Source: Author, 2024)*

Calculation:

$$\text{Sand Cleanliness Against Mud} = \frac{H1}{H2} \times 100\%$$

$$\text{Sand Cleanliness Against Mud 1} = \frac{1}{124} \times 100\% = 0.81\ \%$$

$$\text{Sand Cleanliness Against Mud 2} = \frac{1}{117} \times 100\% = 0.85\ \%$$

8) Analysis of Sand Cleanliness against Material Finer than Sieve No. 200 by Dry Method

Table 4.8 Result data of analysis of sand cleanliness against Mud

| Test No. | 1 | 2 |
|---|---|---|
| Tray Weight | 91 | 187 |
| Dry Sand Weight (W1) | 500 | 500 |
| Tray + Dry Sand | 570 | 664 |
| Net Dry Sand Weight (W2) | 479 | 477 |
| Mud content% | 4.2 | 4.6 |
| Mean | 4.4 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Cleanliness against Mud} = \frac{W1\text{-}W2}{W1} \times 100\%$$

$$\text{Cleanliness against Mud 1} = \frac{500 - 479}{W1} \times 100\% = 4.2\ \%$$

$$\text{Cleanliness against Mud 2} = \frac{500 - 479}{W1} \times 100\% = 4.6\ \%$$

9) Recapitulation of Analysis Result

Table 4.9 Recapitulation of Analysis Result

| No. | Testing | Testing Result | Specification | Standard |
|---|---|---|---|---|
| 1 | Fineness Modulus | 2.39 | 2.0 to 3.3 | ACI E1-07 |
| 2 | Grading Zone | Zone 2 | Zone 2 | SNI 03-2834-2000 |
| 3 | Volume Weight | 1.753 | 1.2 to 1.76 | ACI E1-07 |
| 4 | Relative density | 2.72 | 2.3 to 2.9 | |
| 5 | Moisture | 4.82 | - | SNI 03-1971-1990 |
| 6 | Absorption | 0.81 % | 0.5 to 4 % | ACI E1-07 |
| 7 | Cleanness from material finer than sieve No. 200 | 4.4 % | Max. 5% | |

(Source: Author, 2024)

From the sand material testing, it can be concluded that the characteristics of sand meet the requirements.

### 4.1.2 Crushed Gravel Testing Results

1) Gravel Sieve Analysis
   Weight of Gravel: 15000 grams

Table 4.10 Result data of gravel sieve analysis

| Sieve | | Retained on the Sieve | | | % Cumulative | |
|---|---|---|---|---|---|---|
| No. | mm | Tray + Gravel | Gravel | (%) Retained | Retained | Pass |
| | | (gr) | (gr) | | (%) | (%) |
| 3/2" | 38.1 | 0 | 0 | 0 | 0 | 100 |
| 3/4" | 19 | 5329 | 4793 | 31.95 | 31.95 | 68.05 |
| 3/8" | 9.5 | 10252 | 9716 | 64.77 | 96.73 | 3.27 |
| 4 | 4.75 | 904 | 368 | 2.45 | 99.18 | 0.82 |
| 8 | 2.36 | 544 | 8 | 0.05 | 99.23 | 0.77 |
| 16 | 1.18 | 540 | 4 | 0.03 | 99.26 | 0.74 |
| 30 | 0.6 | 538 | 2 | 0.01 | 99.27 | 0.73 |
| 50 | 0.3 | 537 | 1 | 0.01 | 99.28 | 0.72 |
| 100 | 0. 15 | 0 | 0 | 0.00 | 99.28 | 0.72 |
| Pan | 0 | 0 | 0 | 0.00 | 99.28 | 0.72 |
| Amount | | | 14892 | 99.28 | 624.91 | |
| Fineness Modulus | | ∑% Retained Cumulative/100 | | | 6.25 | |

(*Source: Author, 2024*)

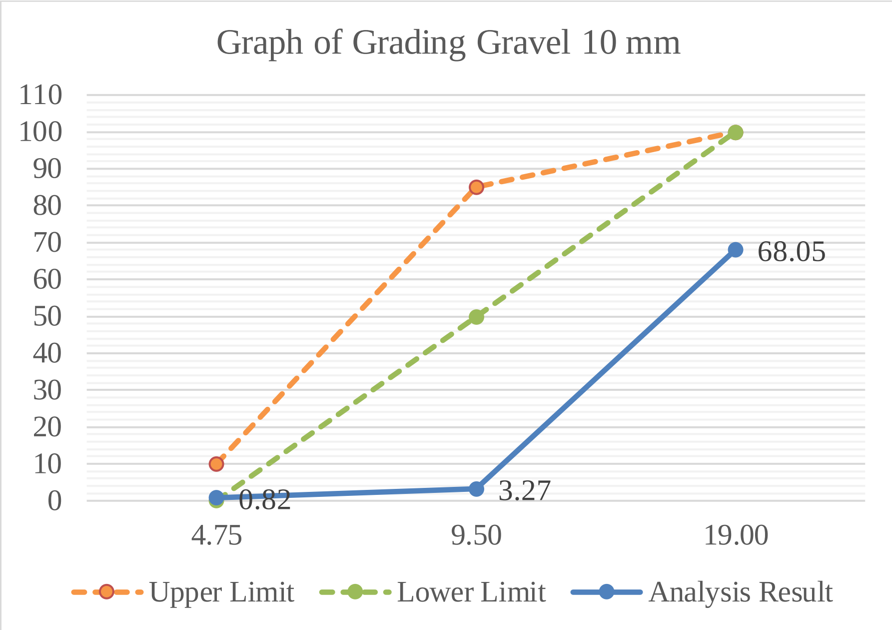



Figure 4.5 Graph of grading gravel diameter 10 mm
(*Source: Author, 2024*)

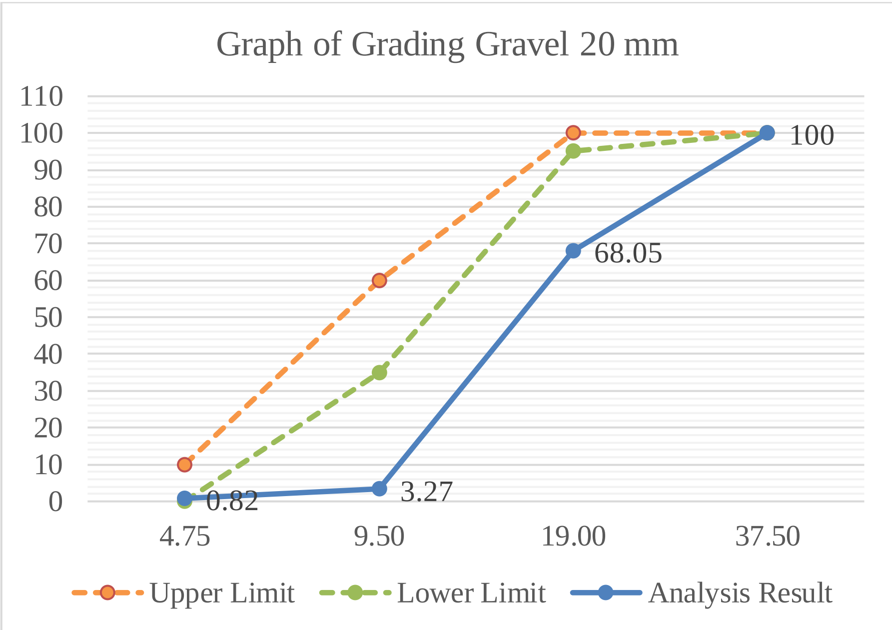
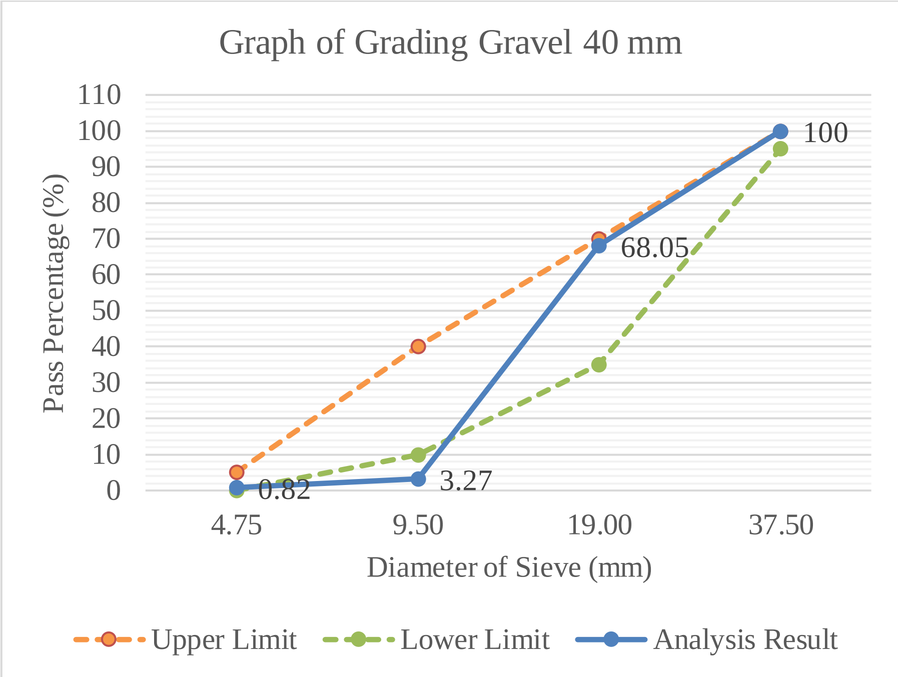



Figure 4.6 Graph of grading gravel diameter 20 mm
(*Sourc: Author, 2024*)




Gambar 4.1 Graph of grading gravel diameter 40 mm
(*Source: Author, 2024*)

From the results of the grave sieve analysis, it is concluded that the sand used in the study is 40 mm grading.

2) Volume Weight Testing of Coarse Aggregate

Table 4.11 Result data of volume weight testing of coarse aggregate

| Test | With Stabbed | | Without Stabbed | |
|---|---|---|---|---|
| | I | II | I | II |
| Cylinder Weight (gr) | 3728 | 3728 | 3728 | 3728 |
| D/H Cylinder (cm) | 15.5/15 | 15.5/15 | 15.5/15 | 15.5/15 |
| Volume of Cylinder ($cm^3$) | 2830.38 | 2830.38 | 2830.38 | 2830.38 |
| Cylinder + Gravel (gr) | 7478 | 7532 | 8169 | 8158 |
| Gravel Weight (gr) | 3750 | 3804 | 4441 | 4430 |
| Weight/Volume ($gr/cm^3$) | 1.325 | 1.344 | 1.569 | 1.565 |
| Mean | 1.334 | | 1.567 | |

(*Source: Author, 2024*)

Calculation without stabbed:

$$\text{Volume Weight} = \frac{\text{(Cylinder Weight+Gravel Weight)-Cylinder Weight}}{\text{Volume of Cylinder}}$$

$$\text{Volume Weight} = \frac{7478 - 3728}{2830.38} = 1.325\ g/cm^3$$

$$\text{Volume Weight} = \frac{7532 - 3728}{2830.38} = 1.344\ g/cm^3$$

Calculation with stabbed:

$$\text{Volume Weight 1} = \frac{8169 - 3728}{2830.38} = 1.569\ g/cm^3$$

$$\text{Volume Weight 2} = \frac{8158 - 3728}{2830.38} = 1.565\ g/cm^3$$

3) Gravel Relative Density

Table 4.12 Gravel relative density analysis

| Test No. | I | II |
|---|---|---|
| Gravel Weight SSD (W1) (g) | 3000 | 3000 |
| Basket Weight (g) | 954 | 954 |
| Gravel Weight in Water (W2) (g) | 1847 | 1866 |
| Basket Weight in Water (W3) (g) | 820 | 820 |
| Gravel Relative Density (Kg/L) | 2.60 | 2.65 |
| Mean | 2.62 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Gravel Relative Density} = \frac{W1}{W1-((W2+W3)-W3)}$$

$$\text{Gravel Relative Density 1} = \frac{3000}{3000-((820+1847)-820)} = 2.60\ kg/l$$

$$\text{Gravel Relative Density 2} = \frac{3000}{3000-((820+1866)-820)} = 2.65\ kg/l$$

4) Gravel Moisture Analysis

Table 4.13 Result data of gravel moisture analysis

| Test No. | I | II |
|---|---|---|
| Tray Weight (gr) | 336 | 345 |
| Teray Weight + Gravel (gr) | 3336 | 3345 |
| Gravel (gr) | 3000 | 3000 |
| Tray Weight + Oven Gravel (gr) | 3324 | 3309 |
| Oven Gravel Weight (gr) | 2988 | 2964 |
| Moisture (%) | 0.40 | 1.21 |
| Mean (%) | 0.81 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Moisture} = \frac{\text{Gravel weight-Oven Gravel Weight}}{\text{Oven Gravel Weight}} \times 100\%$$

$$\text{Moisture 1} = \frac{3000\text{-}2988}{2988} \times 100\% = 0.40\%$$

$$\text{Moisture 2} = \frac{3000\text{-}2964}{2964} \times 100\% = 1.21\%$$

5) Gravel Absorption Testing

Table 4.14 Result of gravel absorption testing

| Test No. | I | II |
|---|---|---|
| Tray Weight (gr) | 141 | 541 |
| Tray Weight + SSD Gravel (gr) | 3141 | 3541 |
| Weight of SSD Gravel (gr) | 3000 | 3000 |
| Tray Weight + Gravel oven (gr) | 3060 | 3453 |
| Oven Gravel Weight (gr) | 2919 | 2912 |
| Gravel Absorption (%) | 2.77 | 3.02 |
| Mean | 2.90 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Gravel Absorption} = \frac{\text{SSD Gravel-Oven Gravel}}{\text{Oven Gravel}} \times 100\%$$

$$\text{Gravel Absorption 1} = \frac{3000\text{-}2919}{2919} \times 100\% = 2.77\%$$

$$\text{Gravel Absorption 2} = \frac{3000\text{-}2912}{2912} \times 100\% = 3.02\%$$

6) Analysis of Gravel Cleanliness Against Material Finer than Sieve No.200

Table 4.15 Analysis of Sand Cleanliness Against Mud by Dry Method

| Test No. | 1 | 2 |
|---|---|---|
| Height of Mud (mm) (H1) | 1 | 1 |
| Height of Gravel (mm) (H2) | 124 | 117 |
| Mud Content % | 0.81 | 0.85 |
| Mean | 0.83 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Gravel Cleanliness Against Mud} = \frac{H1}{H2} \times 100\%$$

$$\text{Gravel Cleanliness Against Mud 1} = \frac{1}{124} \times 100\% = 0.81\ \%$$

$$\text{Gravel Cleanliness Against Mud 2} = \frac{1}{117} \times 100\% = 0.85\ \%$$

7) Gravel Abrasion Testing

Table 4.16 Gravel Abrasion Testing

| Test No. | I | II |
|---|---|---|
| Tray Weight (gr) | 193 | 546 |
| Gravel Weight before Abrasion (gr) | 5000 | 5000 |
| Gravel Weight Retained Sieve 12 after Abrasion + Tray | 3848 | 4177 |
| Gravel Weight Retained Sieve 12 after Abrasion | 3291 | 3631 |
| Abrasion (%) | 26.9 | 27.38 |
| Mean | 27.14 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Abrasion} = \frac{\text{Gravel Initial Weight-Gravel Weight Retained Sieve 12}}{\text{Gravel Initial Weight}} \times 100\%$$

$$\text{Abrasion 1} = \frac{5000\text{-}3848}{5000} \times 100\% = 26.90\%$$

$$\text{Abrasion 2} = \frac{5000\text{-}4177}{5000} \times 100\% = 27.38\%$$

8) Recapitulation of Analysis Result

Table 4.17 Recapitulation of analysis result

| No. | Testing | Testing Result | Specification | Standard |
|---|---|---|---|---|
| 1 | Fineness Modulus | 6.25 | 6.0 – 7.1 | ACI E1-07 |
| 2 | Grading Zone | 40 mm | 10, 20, 40 mm | SNI 03-2834-2000 |
| 3 | Volume Weight | 1.334 | 1.2 to 1.76 | ACI E1-07 |
| 4 | Relative Density | 2.62 | 2.4 to 2.9 | |
| 5 | Moisture | 0.81 | - | SNI 03-1971-1990 |
| 6 | Absorption | 2.90 | 0.5 to 4 % | ACI E1-07 |
| 7 | Cleanness from material finer than sieve No. 200 | 0.83 | Max 1% | |
| 8 | Abrasion | 27.14% | Max 40% | ASTM-C127 |

(*Source: Author, 2024*)

Based on the results of the gravel material test analysis, it is concluded that the gravel meets the standard requirements.

### 4.1.3 Dead Coral Reefs Testing Results

1) Dead Coral Reefs Sieve Analysis

Weight of Coral Reefs: 15000 grams

Table 4.18 Result data of dead coral reefs sieve analysis

| Sieve | | Retained on The Sieve | | | % Cumulative | |
|---|---|---|---|---|---|---|
| No. | mm | Tray + Coral | Coral | (%) Retained Coral | Retained | Pass |
| | | (gr) | (gr) | (%) | (%) | (%) |
| 3/2" | 38.1 | 0 | 0 | 0 | 0 | 100 |
| 3/4" | 19 | 5329 | 4260 | 28.40 | 28.40 | 71.6 |
| 3/8" | 9.5 | 10252 | 9512 | 63.41 | 91.81 | 8.19 |
| 4 | 4.75 | 904 | 1208 | 8.05 | 99.87 | 0.13 |
| 8 | 2.36 | 544 | 7 | 0.05 | 99.91 | 0.09 |
| 16 | 1.18 | 540 | 3 | 0.02 | 99.93 | 0.07 |
| 30 | 0.6 | 538 | 0 | 0.00 | 99.93 | 0.07 |
| 50 | 0.3 | 537 | 0 | 0.00 | 99.93 | 0.07 |
| 100 | 0. 15 | 0 | 0 | 0.00 | 99.93 | 0.07 |
| Pan | 0 | 0 | 0 | 0.00 | 99.93 | 0.07 |
| Amount | | | 14892 | 99.93 | 619.79 | |
| Fineness Modulus | | | | | 6.20 | |

(*Source: Author, 2024*)

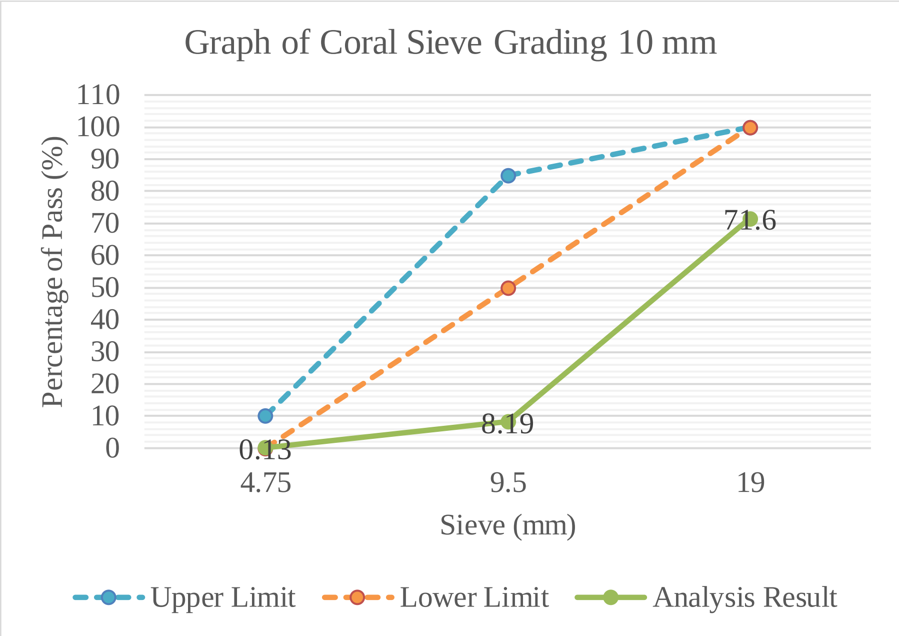



Figure 4.7 Graph of coral reef grading 10 mm
(*Source: Author, 2024*)

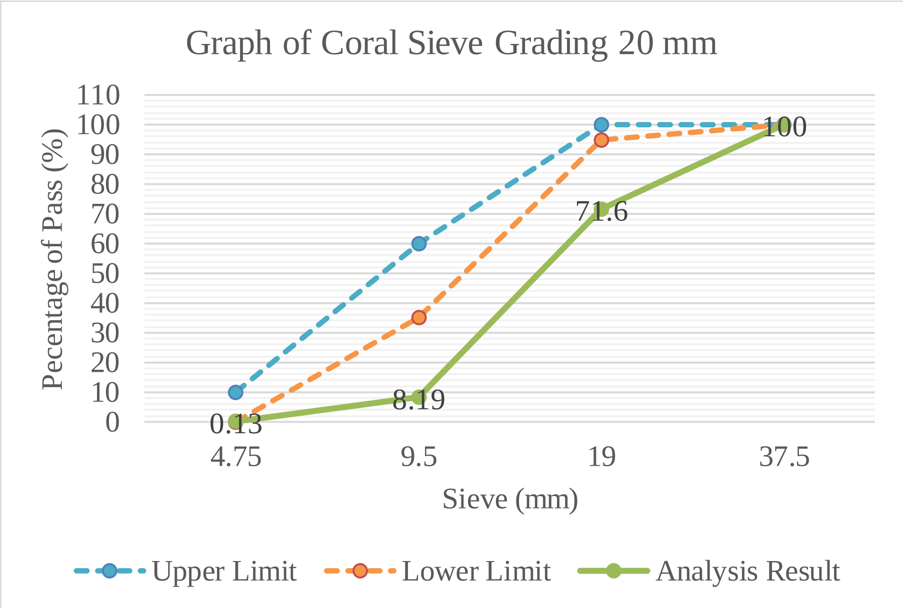



Figure 4.8 Graph of coral reef grading 20 mm
(*Source: Author, 2024*)

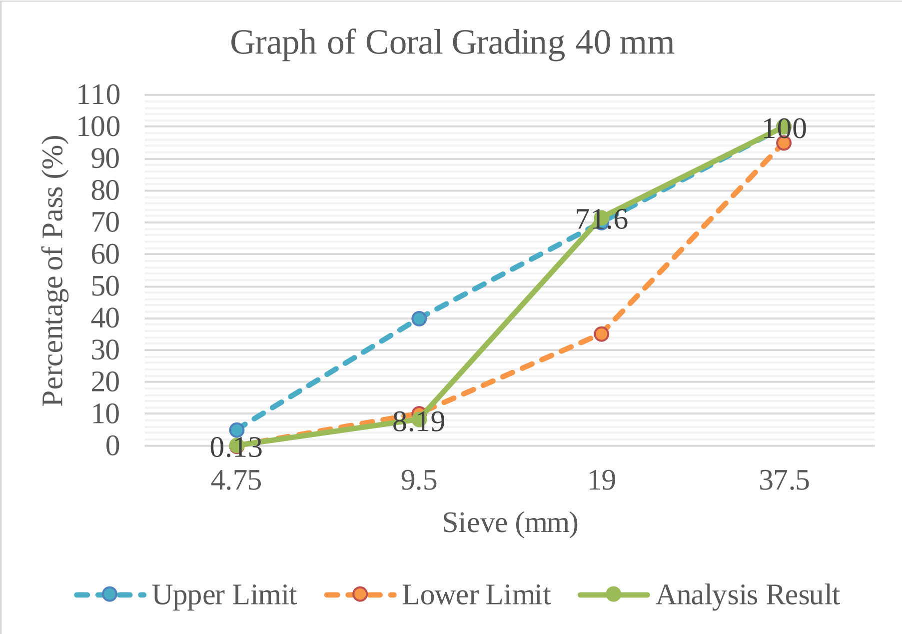



Figure 4.9 Graph of coral reef grading 40 mm

(*Source, Author, 2024*)

From the results of the coral sieve analysis, it was concluded that the corals used in this study were close to 40 mm grading.

2) Coral Reef Volume Weight Testing

Table 4.19 Result data of coral reef volume weight

| Test No. | Without stabbed | | With stabbed | |
|---|---|---|---|---|
| | I | II | I | II |
| Cylinder Weight (A) (gr) | 3728 | 3728 | 3728 | 3728 |
| D/H Cylinder (cm) | 15,5/15 | 15,5/15 | 15,5/15 | 15,5/15 |
| Volume cylinder (V) (cm3) | 2830.38 | 2830.38 | 2830.38 | 2830.38 |
| Cylinder + Coral (B) (gr) | 5961 | 5959 | 6179 | 6241 |
| Coral Weight (gr) | 2233 | 2231 | 2451 | 2513 |
| Weight/volume (gr/cm3) | 0.789 | 0.788 | 0.866 | 0.888 |
| Mean | 0.788 | | 0.877 | |

(*Source: Author, 2024*)

Calculation without stabbed:

$$\text{Volume Weight} = \frac{\text{(Cylinder Weight+Coral Reef Weight)-Cylinder Weight}}{\text{Cylinder Volume}}$$

$$\text{Volume Weight1} = \frac{5961\text{-}3728}{2830.38} = 0.789 \text{ g/cm}^3$$

$$\text{Volume Weight 2} = \frac{5959\text{ -}2231}{2830.38} = 0.788 \text{ g/cm}^3$$

Calculation with stabbed:

$$\text{Volume Weight 1} = \frac{6179 - 2451}{2830.38} = 0.866 \text{ g/cm}^3$$

$$\text{Volume Weight 2} = \frac{6241 - 2513}{2830.38} = 0.888 \text{ g/cm}^3$$

3) Relative Density of Dead Coral Reefs

Table 4.20 Result data of relative density of dead coral reefs testing

| Test No. | I | II |
|---|---|---|
| Coral Weight SSD (W1) (g) | 3000 | 3000 |
| Basket Weight (g) | 954 | 954 |
| Coral Weight in Water (W2) (g) | 2354 | 2308 |
| Basket Weight in Water (W3) (g) | 820 | 820 |
| Coral Relative Density (Kg/L) | 2.046 | 1.984 |
| Mean | 2.015 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Coral Reefs Relative Density} = \frac{W1}{W1\text{-}((W2+W3)\text{-}W3)}$$

$$\text{Relative Density} = \frac{3000}{3000\text{-}((820+2354)\text{-}820)} = 2.046 \text{ Kg/l}$$

$$\text{Relative Density} = \frac{3000}{3000\text{-}((820+2308)\text{-}820)} = 1.984 \text{ Kg/l}$$

4) Dead Coral Reef Moisture Test

Table 4.21 Result data dead coral reef moisture test

| Test No. | I | II |
|---|---|---|
| Tray Weight (gr) | 139 | 536 |
| Tray Weight + Coral (gr) | 3139 | 3536 |
| Coral (gr) | 3000 | 3000 |
| Tray Weight + Oven Coral (gr) | 3042 | 3447 |
| Oven Coral Weight (gr) | 2903 | 2911 |
| Moisture (%) | 3.34 | 3.06 |
| Mean (%) | 3.20 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Moisture} = \frac{\text{Reef Weight-Oven Reef Weight}}{\text{Oven Reef Weight}} \times 100\%$$

$$\text{Moisture 1} = \frac{3000\text{-}2903}{2903} \times 100\% = 3.34\%$$

$$\text{Moisture 2} = \frac{3000 - 2911}{2911} \times 100\% = 3.06\%$$

5) Dead Coral Reef Absorption

Table 4.22 Coral Gravel water absorption test result data

| Experiment Number | I | II |
|---|---|---|
| Tray Weight (gr) | 700 | 1235 |
| Tray Weight + SSD Coral (gr) | 3700 | 4235 |
| Weight of SSD Coral (gr) | 3000 | 3000 |
| Tray Weight + Coral oven (gr) | 3334 | 3887 |
| Oven Coral Weight (gr) | 2634 | 2652 |
| Coral Absorption (%) | 13.90 | 13.12 |
| Mean | 13.51 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Coral Reef Absorption} = \frac{\text{SSD Weight-Oven Reef Weight}}{\text{Oven Reef Weight}} \times 100\%$$

$$\text{Coral Reef Absorption} = \frac{3000\text{-}2634}{2634} \times 100\% = 13.90\%$$

$$\text{Coral Reef Absorption} = \frac{3000\text{-}2652}{2652} \times 100\% = 13.12\%$$

6) Testing of Coral Material Finer than Sieve No. 200 by Dry Method

Table 4.23 Result data of testing of coral sludge content by dry method

| Experiment Number | I | II |
|---|---|---|
| Tray Weight (gr) | 343 | 347 |
| Coral Weight (gr) | 1000 | 1000 |
| Coral + tray (gr) | 1305 | 1310 |
| Coral after Washed (gr) | 962 | 963 |
| Sludge Content (%) | 3.8 | 3.7 |
| Mean (%) | 3.75 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Sludge Content} = \frac{\text{Coral Weight -Coral after Washed}}{\text{Coral Weight}} \times 100\%$$

$$\text{Sludge Content 1} = \frac{1000\text{-}962}{1000} \times 100\% = 3.8\%$$

$$\text{Sludge Content 2} = \frac{1000\text{-}963}{1000} \times 100\% = 3.7\%$$

7) Coral Reefs Abrasion Test

Table 4.24 Result data of coral reefs abrasion test

| Experiment Number | I | II |
|---|---|---|
| Tray Weight (gr) | 543 | 540 |
| Coral Weight before Abrasion (gr) | 5000 | 5000 |
| Coral Weight Retained Sieve 12 after Abrasion + Tray | 2522 | 2530 |
| Coral Weight Retained Sieve 12 after Abrasion | 1979 | 1990 |
| Abrasion (%) | 60.42 | 60.20 |
| Mean | 60.31 | |

(*Source: Author, 2024*)

Calculation:

$$\text{Abrasion} = \frac{\text{Coral Initial Weight-Coral Weight Retained Sieve 12}}{\text{Coral Initial Weight}} \times 100\%$$

$$\text{Abrasion 1} = \frac{5000\text{-}1979}{5000} \times 100\% = 60.42\%$$

$$\text{Abrasion 2} = \frac{5000\text{-}1990}{5000} \times 100\% = 60.20\%$$

8) Recapitulation of Analysis Result

Table 4.25 Recapitulation of dead coral reef test analysis result

| No. | Testing | Testing Result | Specification | Standard |
|---|---|---|---|---|
| 1 | Fineness Modulus | 6.20 | 6.0 – 7.1 | ACI E1-07 |
| 2 | Grading Zone | 40 mm | 10, 20, 40 mm | SNI 03-2834-2000 |
| 3 | Volume Weight | 0.778 | 1.2 to 1.76 | ACI E1-07 |
| 4 | Relative Density | 2.015 | 2.4 to 2.9 | |
| 5 | Moisture | 3.2 | - | SNI 03-1971-1990 |
| 6 | Absorption | 13.51% | 0.5 to 4 % | ACI E1-07 |
| 7 | Cleanness from material finer than sieve No. 200 | 3.75% | Max 1% | |
| 8 | Abrasion | 60.31% | Max 40% | ASTM-C127 |

(*Source: Author, 2024*)

Based on the results of the research on the characteristics of dead coral reefs, it can be concluded that coral reef aggregates do not meet the requirements of normal coarse aggregate characteristics. From this research obtained:

- The specific gravity value of coral aggregate does not meet the requirements of normal aggregate specific gravity, which is consistent with the research conducted by Pangaribuan & Narlis (2015). The specific gravity value of coral aggregate (2.015 g/cm3) is less than that of crushed gravel (2.62 g/cm3), indicating that coral aggregate is lighter than crushed gravel. It also shows that in the same volume, coral aggregate weighs less than crushed gravel aggregate, so the volume weight value of coral aggregate (0.778 g/cm3) is less than crushed gravel aggregate (1.334 g/cm3).
- Coral aggregate has high absorption Wang et al. (2023). The coral aggregate has far more pores than the crushed gravel aggregate so its absorption value (13.51%) is also higher than the absorption value of crushed gravel (2.90%). Coarse aggregates that have many voids make the aggregates absorb water around them (Sultan et al., 2018).
- In this study, the abrasion value of coarse aggregates was 60.31%, which is greater than the abrasion of crushed gravel, which is 27.14%. This shows that coral aggregates are more brittle than gravel aggregates, because the higher the abrasion value, the smaller the aggregate resistance to wear. The higher the abrasion/wear value, the smaller the specific gravity of the coarse aggregate, which is consistent with research conducted by Rondonuwu et al. (2013).

### 4.1.4 Mix Design Analysis of Gravel and Coral

1) 0% Coral Reefs in Coarse Aggregate Admixture

Table 4.26 Analysis of 0% Coral Reefs in Coarse Aggregate Admixture

| Sieve | | Retained | | % Cumulative | | |
|---|---|---|---|---|---|---|
| No. | mm | Coral Reef % | Gravel % | Coral Reef (%) | Gravel (%) | E% |
| | | | | 0.00 | 100 | |
| 3/2" | 37.5 | 100 | 100 | 0 | 100.00 | 100.00 |
| 3/4" | 19 | 71.6 | 68.05 | 0 | 68.05 | 68.05 |
| 3/8" | 9.5 | 8.19 | 3.27 | 0 | 3.27 | 3.27 |
| 4 | 4.75 | 0.13 | 0.82 | 0 | 0.82 | 0.82 |
| 8 | 2.36 | 0.09 | 0.77 | 0 | 0.77 | 0.77 |
| 16 | 1.18 | 0.07 | 0.74 | 0 | 0.74 | 0.74 |
| 30 | 0.6 | 0.07 | 0.73 | 0 | 0.73 | 0.73 |
| 50 | 0.3 | 0.07 | 0.72 | 0 | 0.72 | 0.72 |
| 100 | 0. 15 | 0.07 | 0.72 | 0 | 0.72 | 0.72 |
| Pan | 0 | 0.07 | 0.72 | 0 | 0.72 | 0.72 |

(*Source: Author, 2024*)

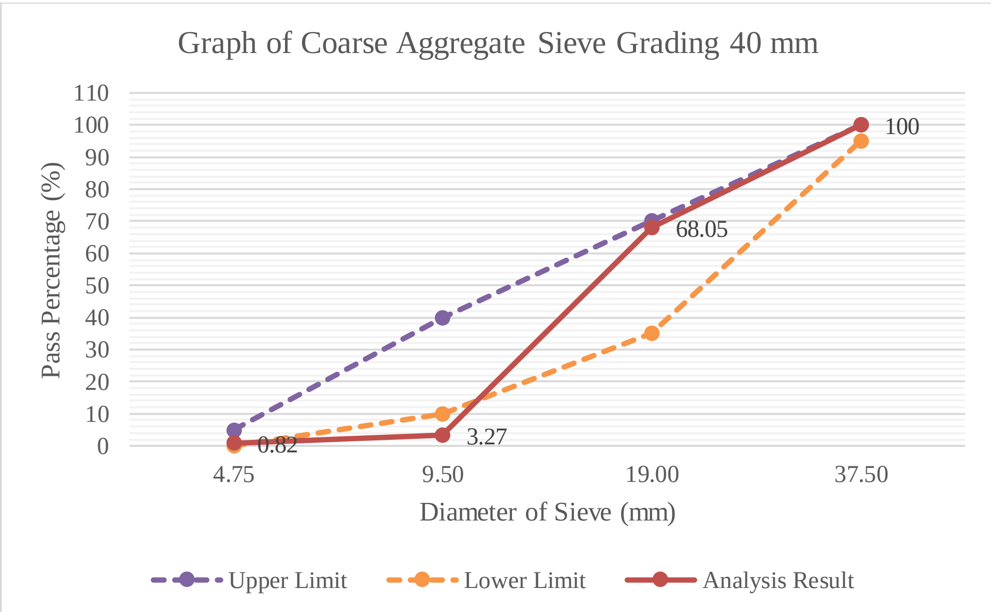



Figure 4.10 Graph of 0% coral in coarse aggregate combine, grade 40 mm
(*Source, Author, 2024*)

2) 25% Coral Reefs in Coarse Aggregate Admixture

Table 4.27 25% Coral Reefs in Coarse Aggregate Admixture

| Sieve | | Retained | | % Cumulative | | |
|---|---|---|---|---|---|---|
| No. | mm | Coral Reef % | Gravel % | Coral Reef (%) | Gravel (%) | E% |
| | | | | 25 | 75 | |
| 3/2" | 37.5 | 100 | 100 | 25 | 75.00 | 100.00 |
| 3/4" | 19 | 71.6 | 68.05 | 17.9 | 51.04 | 68.94 |
| 3/8" | 9.5 | 8.19 | 3.27 | 2.0475 | 2.45 | 4.50 |
| 4 | 4.75 | 0.13 | 0.82 | 0.03 | 0.62 | 0.65 |
| 8 | 2.36 | 0.09 | 0.77 | 0.02 | 0.58 | 0.60 |
| 16 | 1.18 | 0.07 | 0.74 | 0.02 | 0.56 | 0.57 |
| 30 | 0.6 | 0.07 | 0.73 | 0.02 | 0.55 | 0.57 |
| 50 | 0.3 | 0.07 | 0.72 | 0.02 | 0.54 | 0.56 |
| 100 | 0. 15 | 0.07 | 0.72 | 0.02 | 0.54 | 0.56 |

(*Source: Author,2024*)

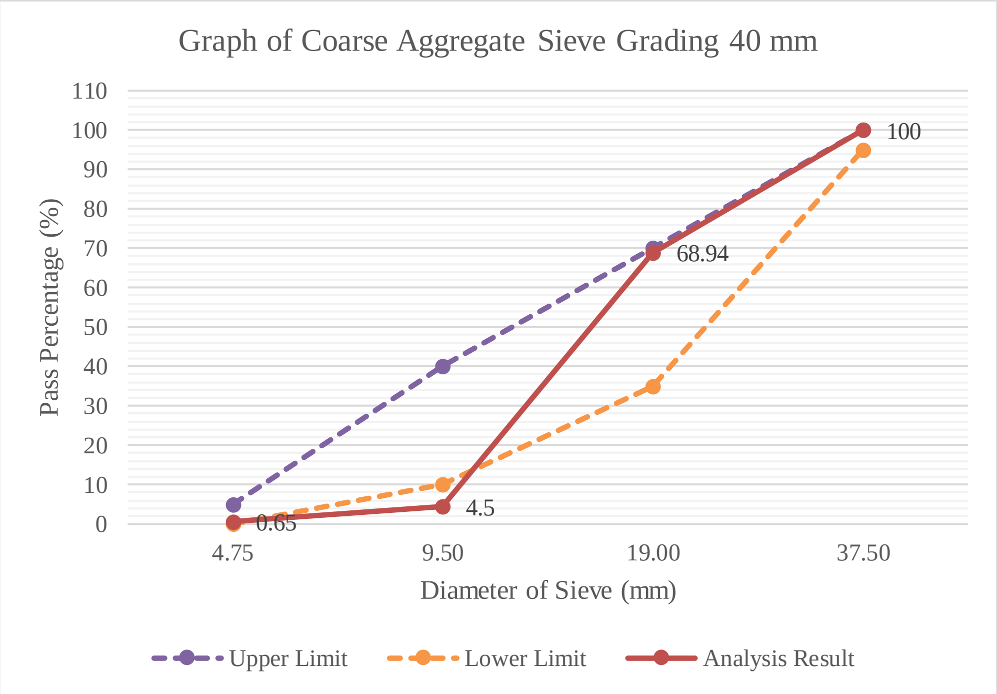



Figure 4.11 Graph of 25% coral in coarse aggregate combine, grade 40 mm

(*Source: Author, 2024*)

3) 50% Coral Reefs in Coarse Aggregate Admixture

Table 4.28 50% Coral Reefs in Coarse Aggregate Admixture

| Sieve | | Retained | | % Cumulative | | |
|---|---|---|---|---|---|---|
| No. | mm | Coral Reef % | Gravel % | Coral Reef (%) | Gravel (%) | E% |
| | | | | 50 | 50 | |
| 3/2" | 37.5 | 100 | 100 | 50.00 | 50.00 | 100.00 |
| 3/4" | 19 | 71.6 | 68.05 | 35.80 | 34.03 | 69.83 |
| 3/8" | 9.5 | 8.19 | 3.27 | 4.10 | 1.64 | 5.73 |
| 4 | 4.75 | 0.13 | 0.82 | 0.07 | 0.41 | 0.48 |
| 8 | 2.36 | 0.09 | 0.77 | 0.05 | 0.39 | 0.43 |
| 16 | 1.18 | 0.07 | 0.74 | 0.04 | 0.37 | 0.41 |
| 30 | 0.6 | 0.07 | 0.73 | 0.04 | 0.37 | 0.40 |
| 50 | 0.3 | 0.07 | 0.72 | 0.04 | 0.36 | 0.40 |
| 100 | 0. 15 | 0.07 | 0.72 | 0.04 | 0.36 | 0.40 |

(*Source: Author, 2024*)

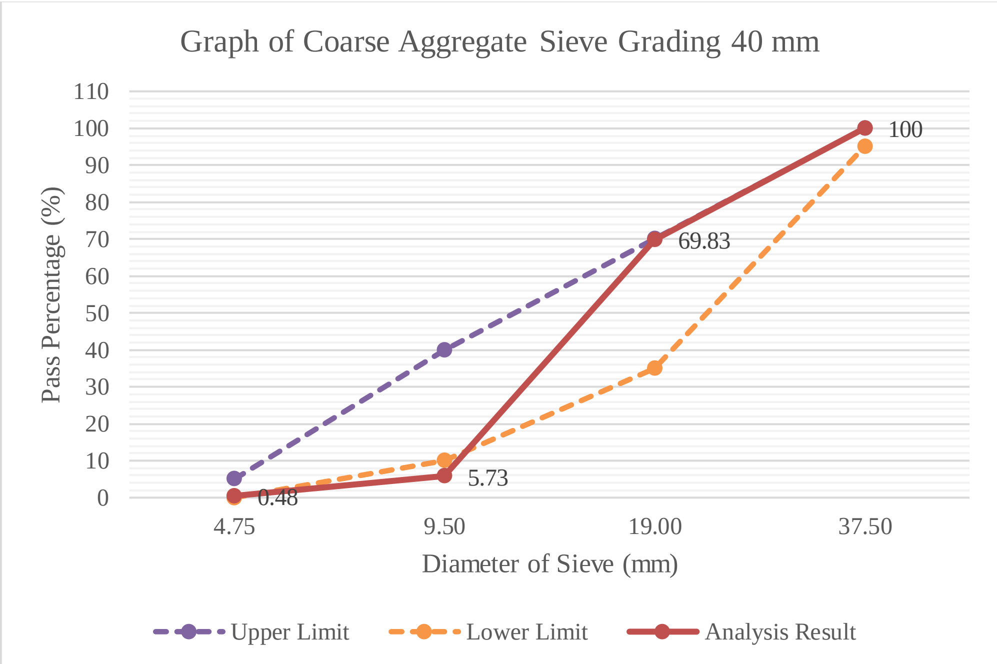



Figure 4.12 Graph of 50% coral in coarse aggregate combine, grade 40 mm

(*Source: Author, 2024*)

4) 60% Coral Reefs in Coarse Aggregate Admixture

Table 4.29 60% Coral Reefs in Coarse Aggregate Admixture

| Sieve | | Retained | | %Cumulative | | |
|---|---|---|---|---|---|---|
| No. | mm | Coral Reef % | Gravel % | Coral Reef (%) | Gravel (%) | E% |
| | | | | 60 | 40 | |
| 3/2" | 37.5 | 100 | 100 | 60.00 | 40.00 | 100.00 |
| 3/4" | 19 | 71.6 | 68.05 | 42.96 | 27.22 | 70.18 |
| 3/8" | 9.5 | 8.19 | 3.27 | 4.91 | 1.31 | 6.22 |
| 4 | 4.75 | 0.13 | 0.82 | 0.08 | 0.33 | 0.41 |
| 8 | 2.36 | 0.09 | 0.77 | 0.05 | 0.31 | 0.36 |
| 16 | 1.18 | 0.07 | 0.74 | 0.04 | 0.30 | 0.34 |
| 30 | 0.6 | 0.07 | 0.73 | 0.04 | 0.29 | 0.33 |
| 50 | 0.3 | 0.07 | 0.72 | 0.04 | 0.29 | 0.33 |
| 100 | 0. 15 | 0.07 | 0.72 | 0.04 | 0.29 | 0.33 |

(*Source: Author, 2024*)

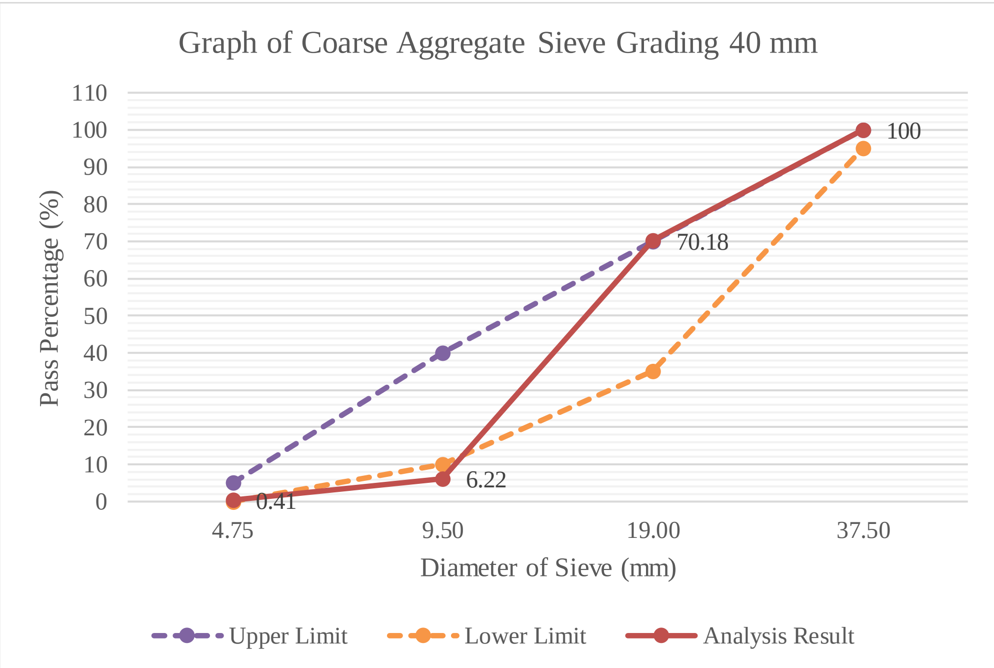



Figure 4.13 Graph of 60% coral in coarse aggregate combine, grade 40 mm
(*Source: Author, 2024*)

5) 75% Coral Reefs in Coarse Aggregate Admixture

Table 4.30 75% Coral Reefs in Coarse Aggregate Admixture

| Sieve | | Retained | | %Cumulative | | |
|---|---|---|---|---|---|---|
| No. | mm | Coral Reef % | Gravel % | Coral Reef (%) | Gravel (%) | E% |
| | | | | 0.75 | 0.25 | |
| 3/2" | 37.5 | 100 | 100 | 75.00 | 25.00 | 100.00 |
| 3/4" | 19 | 71.6 | 68.05 | 53.70 | 17.01 | 70.71 |
| 3/8" | 9.5 | 8.19 | 3.27 | 6.14 | 0.82 | 6.96 |
| 4 | 4.75 | 0.13 | 0.82 | 0.10 | 0.21 | 0.30 |
| 8 | 2.36 | 0.09 | 0.77 | 0.07 | 0.19 | 0.26 |
| 16 | 1.18 | 0.07 | 0.74 | 0.05 | 0.19 | 0.24 |
| 30 | 0.6 | 0.07 | 0.73 | 0.05 | 0.18 | 0.24 |
| 50 | 0.3 | 0.07 | 0.72 | 0.05 | 0.18 | 0.23 |
| 100 | 0.15 | 0.07 | 0.72 | 0.05 | 0.18 | 0.23 |

(*Source: Author, 2024*)

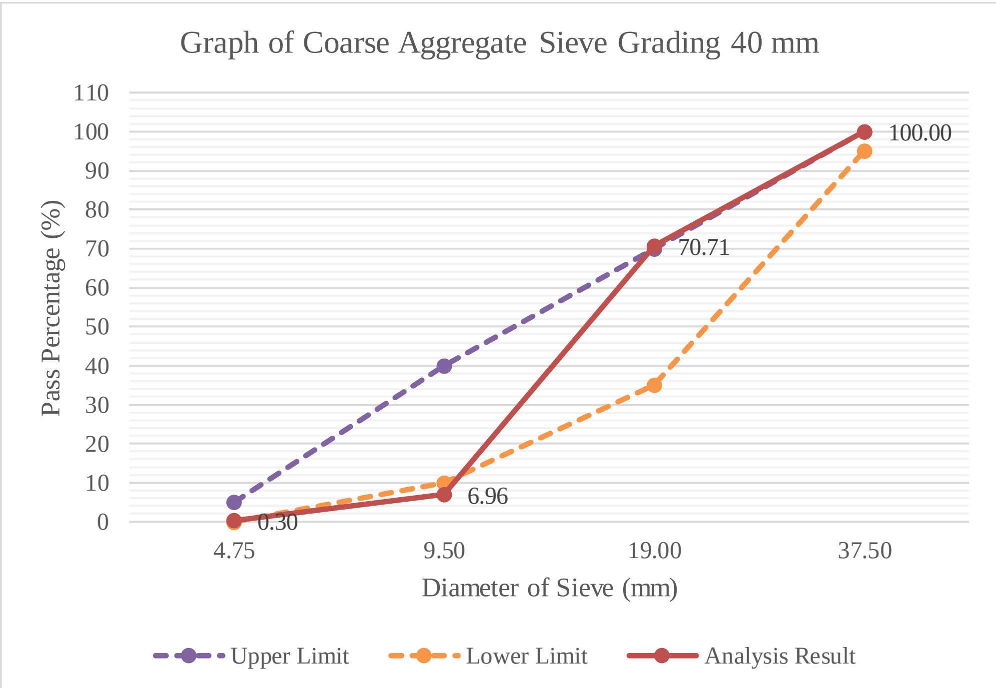



Figure 4.14 Graph of 75% coral in coarse aggregate combine, grade 40 mm

(*Source: Author, 2024*)

## 4.2 Mix Design of Sand, Gravel, and Coral

1) Coral 0% in Combine Aggregate

Table 4.31 Analysis of coral 0% in Combine Aggregate

| No. | mm | Sand | Gravel | Coral Reef | Sand | Gravel | Coral Reef | E |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | | | | (%) |
| | | | | | 39% | 61% | 0% | |
| 3/2" | 37.5 | 100 | 100 | 100 | 39.00 | 61.00 | 0.00 | 100.00 |
| 3/4" | 19 | 100 | 68.05 | 71.6 | 39.00 | 41.51 | 0.00 | 80.51 |
| 3/8" | 9.5 | 100 | 3.27 | 8.19 | 39.00 | 1.99 | 0.00 | 40.99 |
| 4 | 4.75 | 96.2 | 0.82 | 0.13 | 37.52 | 0.50 | 0.00 | 38.02 |
| 8 | 2.36 | 90.5 | 0.77 | 0.09 | 35.30 | 0.47 | 0.00 | 35.76 |
| 16 | 1.18 | 75.2 | 0.74 | 0.07 | 29.33 | 0.45 | 0.00 | 29.78 |
| 30 | 0.6 | 52.1 | 0.73 | 0.07 | 20.32 | 0.45 | 0.00 | 20.76 |
| 50 | 0.3 | 34.4 | 0.72 | 0.07 | 13.42 | 0.44 | 0.00 | 13.86 |
| 100 | 0.15 | 12.2 | 0.72 | 0.07 | 4.76 | 0.44 | 0.00 | 5.20 |

(*Source: Author, 2024*)

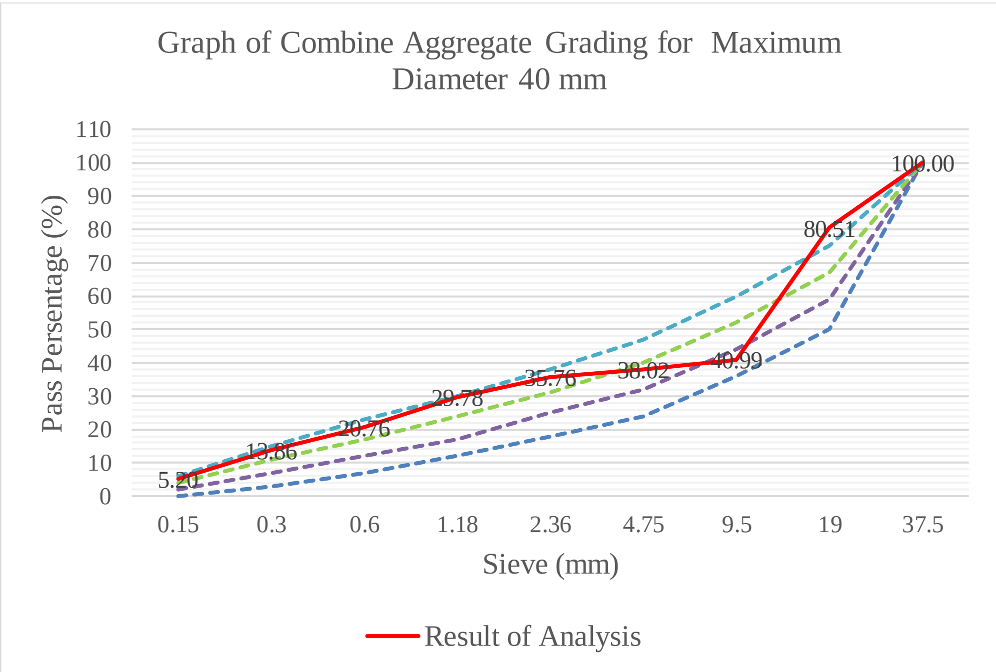



Figure 4.15 Graph of combine aggregate grading with 0% coral content
(*Source: Author, 2024*)

2) Coral 25% in Combine Aggregate

Table 4.32 Analysis of coral 25% in Combine Aggregate

| No. | mm | Sand | Gravel | Coral Reef | Sand | Gravel | Coral Reef | E |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | | | | (%) |
| | | | | | 39% | 45.75% | 15.25% | |
| 3/2" | 37.5 | 100 | 100 | 100 | 39.00 | 45.75 | 15.25 | 100.00 |
| 3/4" | 19 | 100 | 68.05 | 71.6 | 39.00 | 31.13 | 10.92 | 81.05 |
| 3/8" | 9.5 | 100 | 3.27 | 8.19 | 39.00 | 1.50 | 1.25 | 41.75 |
| 4 | 4.75 | 96.2 | 0.82 | 0.13 | 37.52 | 0.38 | 0.02 | 37.91 |
| 8 | 2.36 | 90.5 | 0.77 | 0.09 | 35.30 | 0.35 | 0.01 | 35.66 |
| 16 | 1.18 | 75.2 | 0.74 | 0.07 | 29.33 | 0.34 | 0.01 | 29.68 |
| 30 | 0.6 | 52.1 | 0.73 | 0.07 | 20.32 | 0.33 | 0.01 | 20.66 |
| 50 | 0.3 | 34.4 | 0.72 | 0.07 | 13.42 | 0.33 | 0.01 | 13.76 |
| 100 | 0.15 | 12.2 | 0.72 | 0.07 | 4.76 | 0.33 | 0.01 | 5.10 |

(*Source: Author, 2024*)

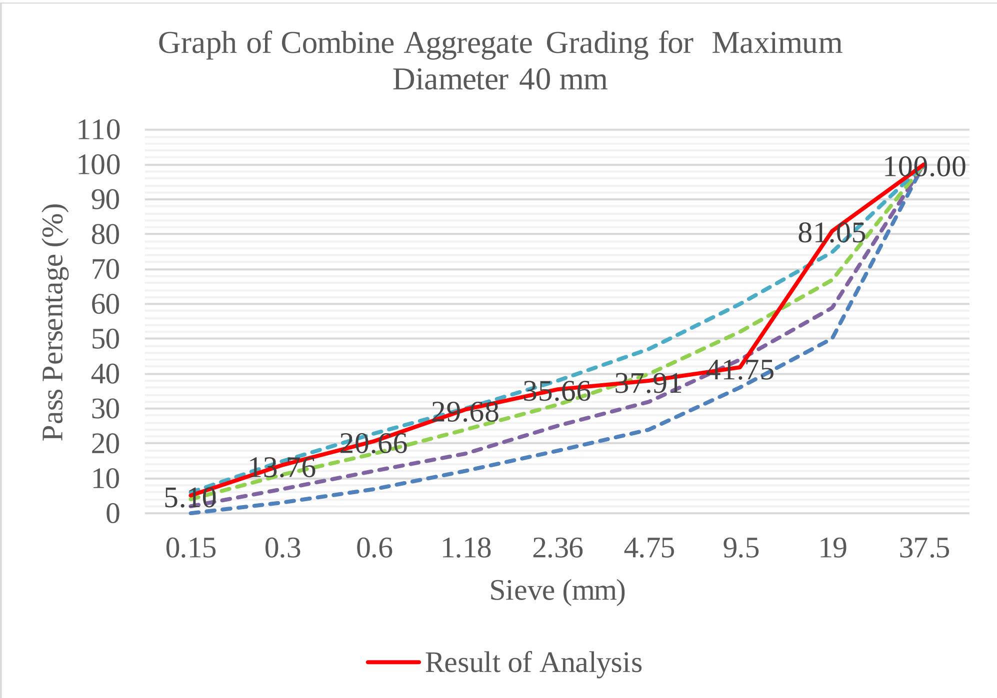



Figure 4.16 Graph of combine aggregate grading with 25% coral content

(*Source: Author, 2024*)

3) Coral 50% in Combine Aggregate

Table 4.33 Analysis of coral 50% in Combine Aggregate

| No. | mm | Sand | Gravel | Coral Reef | Sand | Gravel | Coral Reef | E |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | | | | (%) |
| | | | | | 39% | 30.5% | 30.5% | |
| 3/2" | 37.5 | 100 | 100 | 100 | 39.00 | 30.50 | 30.50 | 100.00 |
| 3/4" | 19 | 100 | 68.05 | 71.6 | 39.00 | 20.76 | 21.48 | 81.24 |
| 3/8" | 9.5 | 100 | 3.27 | 8.19 | 39.00 | 1.00 | 2.46 | 42.45 |
| 4 | 4.75 | 96.2 | 0.82 | 0.13 | 37.52 | 0.25 | 0.04 | 37.81 |
| 8 | 2.36 | 90.5 | 0.77 | 0.09 | 35.30 | 0.23 | 0.03 | 35.56 |
| 16 | 1.18 | 75.2 | 0.74 | 0.07 | 29.33 | 0.23 | 0.02 | 29.57 |
| 30 | 0.6 | 52.1 | 0.73 | 0.07 | 20.32 | 0.22 | 0.02 | 20.56 |
| 50 | 0.3 | 34.4 | 0.72 | 0.07 | 13.42 | 0.22 | 0.02 | 13.66 |
| 100 | 0.15 | 12.2 | 0.72 | 0.07 | 4.76 | 0.22 | 0.02 | 5.00 |

(*Source: Author, 2024*)

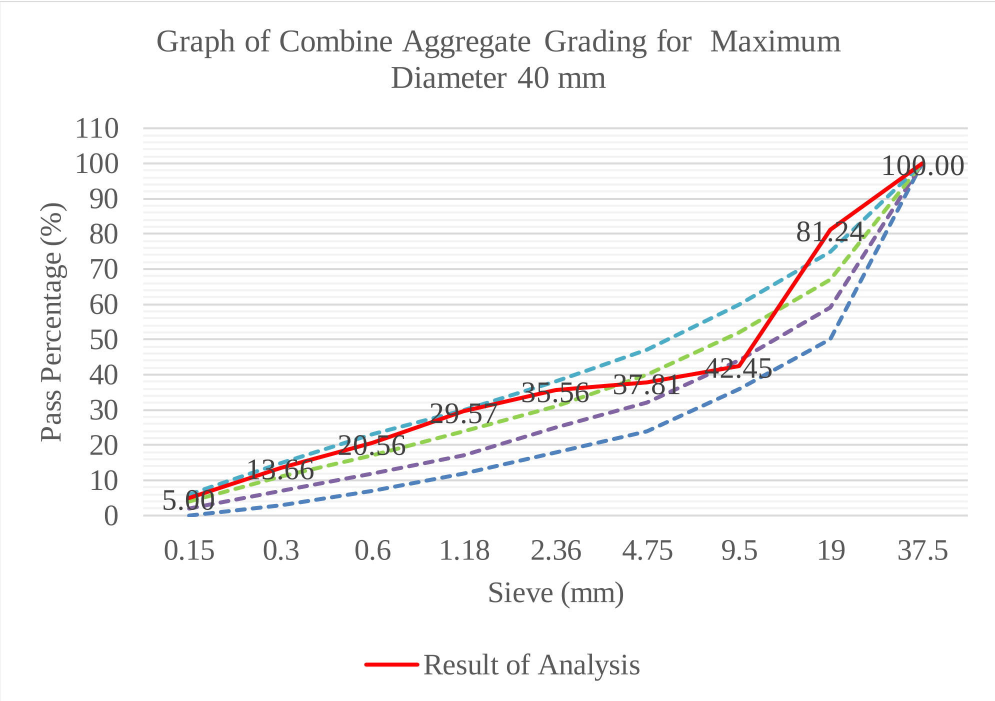



Figure 4.17 Graph of combine aggregate grading with 50% coral content

(*Source: Author, 2024*)

4) Coral 60% in Combine Aggregate

Table 4.34 Analysis of coral 60% in Combine Aggregate

| No. | mm | Sand | Gravel | Coral Reef | Sand | Gravel | Coral Reef | E |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | | | | (%) |
| | | | | | 39.0% | 24.4% | 36.6% | |
| 3/2" | 37.5 | 100 | 100 | 100 | 39.00 | 24.40 | 36.60 | 100.00 |
| 3/4" | 19 | 100 | 68.05 | 71.6 | 39.00 | 16.60 | 26.21 | 81.81 |
| 3/8" | 9.5 | 100 | 3.27 | 8.19 | 39.00 | 0.80 | 3.00 | 42.80 |
| 4 | 4.75 | 96.2 | 0.82 | 0.13 | 37.52 | 0.20 | 0.05 | 37.77 |
| 8 | 2.36 | 90.5 | 0.77 | 0.09 | 35.30 | 0.19 | 0.03 | 35.52 |
| 16 | 1.18 | 75.2 | 0.74 | 0.07 | 29.33 | 0.18 | 0.03 | 29.53 |
| 30 | 0.6 | 52.1 | 0.73 | 0.07 | 20.32 | 0.18 | 0.03 | 20.52 |
| 50 | 0.3 | 34.4 | 0.72 | 0.07 | 13.42 | 0.18 | 0.03 | 13.62 |
| 100 | 0.15 | 12.2 | 0.72 | 0.07 | 4.76 | 0.18 | 0.03 | 4.96 |

(*Source: Author, 2024*)

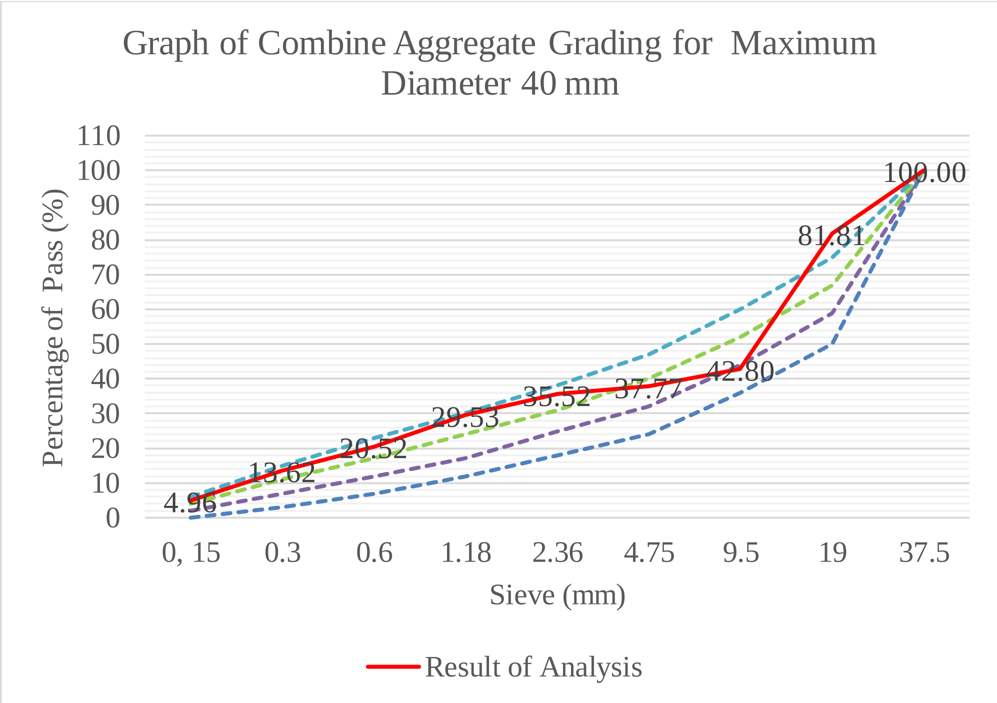



Figure 4.18 Graph of combine aggregate grading with 60% coral content

(*Source: Author, 2024*)

5) Coral 75% in Combine Aggregate

Table 4.35 Analysis of coral 75% in Combine Aggregate

| No. | mm | Sand | Gravel | Coral Reef | Sand | Gravel | Coral Reef | E |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | | | | (%) |
| | | | | | 39.00% | 15.25% | 45.75% | |
| 3/2" | 37.5 | 100 | 100 | 100 | 39.00 | 15.25 | 45.75 | 100.00 |
| 3/4" | 19 | 100 | 68.05 | 71.6 | 39.00 | 10.38 | 32.76 | 82.13 |
| 3/8" | 9.5 | 100 | 3.27 | 8.19 | 39.00 | 0.50 | 3.75 | 43.25 |
| 4 | 4.75 | 96.2 | 0.82 | 0.13 | 37.52 | 0.13 | 0.06 | 37.70 |
| 8 | 2.36 | 90.5 | 0.77 | 0.09 | 35.30 | 0.12 | 0.04 | 35.45 |
| 16 | 1.18 | 75.2 | 0.74 | 0.07 | 29.33 | 0.11 | 0.03 | 29.47 |
| 30 | 0.6 | 52.1 | 0.73 | 0.07 | 20.32 | 0.11 | 0.03 | 20.46 |
| 50 | 0.3 | 34.4 | 0.72 | 0.07 | 13.42 | 0.11 | 0.03 | 13.56 |
| 100 | 0.15 | 12.2 | 0.72 | 0.07 | 4.76 | 0.11 | 0.03 | 4.90 |

(*Source: Author, 2024*)

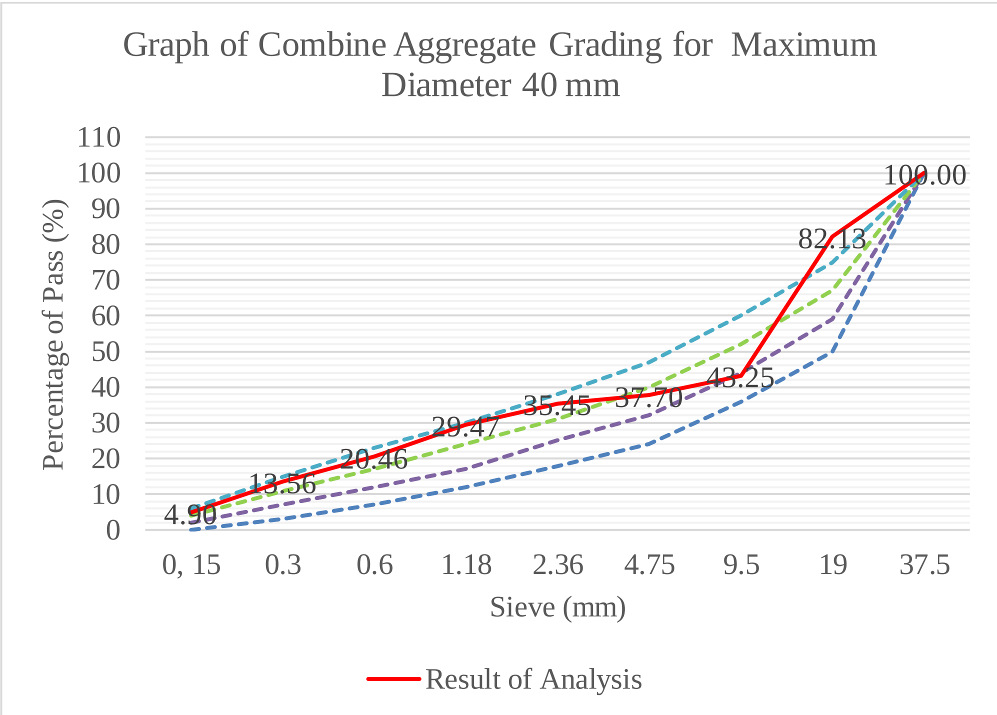



Figure 4.19 Graph of combine aggregate grading with 75% coral content

(*Source: Author, 2024*)

## 4.3 Mix Design Analysis

### 4.3.1 Mix Design Form

Table 4.36 Mix design analysis

| No | Description | Term/Reference | Value | |
|---|---|---|---|---|
| 1 | Characteristic compressive strength (f'c) | Determined | 14.5 MPa (175 kg/cm$^2$) at 28 days. 5% defect | |
| 2 | Standard deviation (s) | Unknown from previous data | - | |
| 3 | Margin (m) | SNI 03-2847-2013 | 7 MPa (70 kg/cm$^2$) | |
| 4 | Average strength to be achieved | 1+3 | 175 + 70 = 245 kg/cm$^2$ | |
| 5 | Type of cement | Retrieved | Portland type 1 | |
| 6 | Type of Aggregate | Coarse | Crushed gravel and dead coral reef | |
| | | Fine | Sand (natural) | |
| 7 | Water cement factor | SNI 03-2834-2000 | 0.68 | |
| 8 | Water cement factor maximum | SNI 03-2834-2000 | 0.60 | |
| 9 | Slump | SNI 03-2834-2000 | 100 | mm |
| 10 | Maximum size aggregate | SNI 03-2834-2000 | 40 | mm |
| 11 | Free water content | SNI 03-2834-2000 | 185 | Kg/m$^3$ |
| 12 | Cement content | 11:7 or 11:8 | 185 : 0.60 = 308.33 | Kg/cm$^3$ |
| 13 | Maximum cement content | | There is no requirement in this case | |
| 14 | Minimum cement content | SNI 03-2834-2000 | 275 | Kg/cm$^3$ |
| 15 | Water cement factor adjusted | 11:275 | 0.60 | |
| 16 | Grain size arrangement of fine aggregate | SNI 03-2834-2000 | Area (zone) of grain arrangement | 2 |

Table 4.37 Mix design analysis continue

| No | Description | Term/Reference | Value | | |
|---|---|---|---|---|---|
| 17 | Percent finer material than 4.8 mm | SNI 03-2834-2000 | 39 | | % |
| 18 | Relative density of SSD aggregate | | 2.66 | | 0% |
| | | | 2.57 | | 25% |
| | | | 2.47 | | 50% |
| | | | 2.44 | | 60% |
| | | | 2.38 | | 75% |
| 19 | Concrete unit weight | SNI 03-2834-2000 | 2.66 | $Kg/cm^3$ | 0% |
| | | | 2.57 | $Kg/cm^3$ | 25% |
| | | | 2.47 | $Kg/cm^3$ | 50% |
| | | | 2.44 | $Kg/cm^3$ | 60% |
| | | | 2.38 | $Kg/cm^3$ | 75% |
| 20 | Weight of combined aggregate | 19 – 11 – 12 | 2408 | $Kg/cm^3$ | 0% |
| | | | 2344 | $Kg/cm^3$ | 25% |
| | | | 2275 | $Kg/cm^3$ | 50% |
| | | | 2256 | $Kg/cm^3$ | 60% |
| | | | 2219 | $Kg/cm^3$ | 75% |
| 21 | Fine aggregate weight | 20 x 17 | 1914.67 | $Kg/cm^3$ | 0% |
| | | | 1850.67 | $Kg/cm^3$ | 25% |
| | | | 1781.67 | $Kg/cm^3$ | 50% |
| | | | 1762.67 | $Kg/cm^3$ | 60% |
| | | | 1725.67 | $Kg/cm^3$ | 75% |
| 22 | Coral reef weight | %Coral reef x (20 – 21) | 746.72 | $Kg/cm^3$ | 0% |
| | | | 721.76 | $Kg/cm^3$ | 25% |
| | | | 694.85 | $Kg/cm^3$ | 50% |
| | | | 687.44 | $Kg/cm^3$ | 60% |
| | | | 673.01 | $Kg/cm^3$ | 75% |
| 23 | Gravel weight | 20 – 21 - 22 | 0.00 | $Kg/cm^3$ | 0% |
| | | | 282.23 | $Kg/cm^3$ | 25% |
| | | | 543.41 | $Kg/cm^3$ | 50% |
| | | | 645.14 | $Kg/cm^3$ | 60% |
| | | | 789.49 | $Kg/cm^3$ | 75% |

(*Source: Author, 2024*)

### 4.3.2 Explanation of Form Filling

1. The required compressive strength has been set at 14.5 MPa at 28 days.
2. Standard deviation data is not available because there is no previous data
3. The margin value is based on SNI 2847-2013 because there is no standard deviation data, then for f'c which is less than 21 MPa, the added value is determined by the table which is 7.0 MPa.

Table 4.38 The average strength is necessary

| Required compressive strength (MPa) | Average compressive strength required (MPa) |
|---|---|
| f'c < 21 | f'cr = f'c + 7.0 |
| 21 ≤ f'c ≤ 35 | f'cr = f'c + 8.3 |
| f'c > 35 | f'cr = 1.10f'c + 5.0 |

(*Source: SNI 2847-2013*)

4. Calculation of average compressive strength

   F'cr = f'c + 7.0

   = 14.5 + 7.0 = 21.5 MPa
5. Type of cement specified Portland type I
6. Type of aggregate:
   - Natural fine aggregate, namely Lumajang sand
   - Coarse aggregate of crushed gravel and coral
7. The free cement water factor based on SNI 03-2834-2000 is determined from the graph below. From the table, it is known that the coarse aggregate of crushed gravel and type I cement has an expected compressive strength at 28 days of age of 37 MPa with a cement water factor of 0.50. This value was used to create a curve to be followed based on the following figure:

Table 4.39 Estimated compressive strength (MPa) of concrete in Indonesia

| Type of cement | Type of Coarse Aggregate | Compressive Strength (MPa) | | | | |
|---|---|---|---|---|---|---|
| | | At the age (days) | | | | Shape |
| | | 3 | 7 | 28 | 29 | Shape of Specimen |
| Portland Cement type I | Uncrushed stone | 17 | 23 | 33 | 40 | Cylinder |
| | Crushed stone | 19 | 27 | 37 | 45 | |
| Sulphate Resistance Cement Type II, V | Uncrushed Stone | 20 | 28 | 40 | 48 | Cube |
| | Crushed stone | 25 | 32 | 45 | 54 | |
| Portland Cement Type III | Uncrushed stone | 21 | 28 | 38 | 44 | Cylinder |
| | Crushed stone | 25 | 33 | 44 | 48 | |
| | Uncrushed stone | 25 | 31 | 46 | 53 | Cube |
| | Crushed stone | 30 | 40 | 53 | 60 | |

(*Source: SNI 03-2834-2000*)

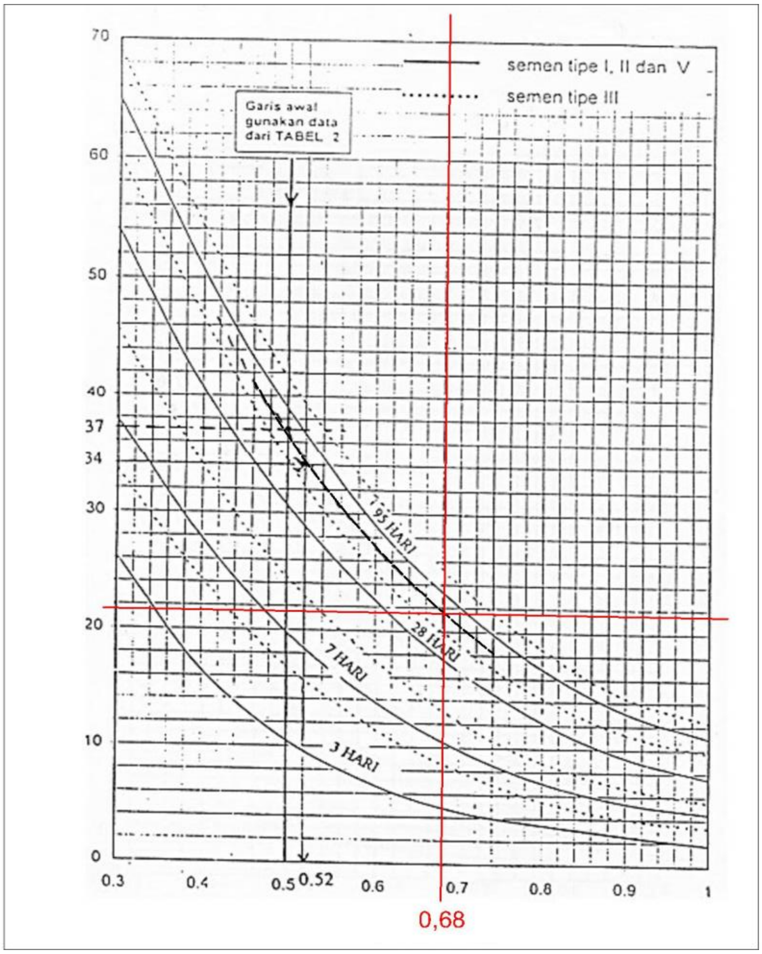



Figure 4.20 Graph of the relationship between compressive strength and W/C
(Cylinder diameter 150 mm, length 300 mm)
(*Source: SNI 03-2834-2000*)

From the point of compressive strength of 37 MPa, a line is drawn until it intersects the center line indicating a cement water factor of 0.50. Then a curve is drawn through the intersection point made, the curve is shaped approximately the same as the curve above and below it (dotted line). The concrete batching plant is designed to produce concrete that is suitable for all kinds of construction projects, including roads, bridges, dams, airports, airports, and other construction sites. This is the first time that a concrete batch plant has been built, and it's the first time that a concrete batch plant has been built. In this study obtained 0.68.

8. The maximum cement water factor obtained from SNI 2847-2013 in the following table is 0.60

Table 4.40 Requirements for the minimum cement and maximum W/C

| Location | Minimum Cement Amount Per $m^3$ of Concrete (kg) | Maximum Water Cement Factor Value |
|---|---|---|
| Indoor concrete: | | |
| c) Non-corrosive surrounding | 275 | 0.60 |
| d) Corrosive surrounding caused by condensation and corrosive vapor | 325 | 0.52 |
| Outdoor concrete: | | |
| c) Unprotected from rain and direct sunlight | 325 | 0.60 |
| d) Protected from rain and direct sunlight | 275 | 0.60 |
| Concrete into the ground: | | |
| c) Experiences wet and dry alternately | 325 | 0.55 |
| d) Under the influence of sulfate and alkali from the soil | | See table 5 |
| Continuous concrete related: | | |
| c) Water | | |
| d) Salt water | | See table 6 |

(*Source: SNI 03-2834-2000*)

9. The planned slump value is 100 mm obtained from the table below. The concrete made is assumed to be used for ground floor slabs and walls, hence a value between 7.5 cm - 15 cm is taken.

Table 4. 41 slump value for variation construction

| **Concrete usage based on the type of structure being made** | **Slump Value (cm)** | |
|---|---|---|
| | **Maximum** | **Minimum** |
| Walls, foundation plates and reinforced sole foundations | 12.5 | 5 |
| Unreinforced footings, caissons and below-ground structures | 9 | 2.5 |
| Plate, beam, column, wall | 15 | 7.5 |
| Road pavement | 7.5 | 5 |
| Mass concreting (mass concrete) | 7.5 | 2.5 |

(*Source: SNI 2847-2013*)

10. Maximum aggregate size set at 40 mm
11. Free water content based on SNI 03-2834-2000

Table 4.42 Estimated free water content (kg/m$^3$)

| Slump | | 0-10 | 0-30 | 30-60 | 60-180 |
|---|---|---|---|---|---|
| Aggregate grain size maximum | Type of aggregate | | | | |
| 10 | Uncrushed aggregate | 150 | 180 | 205 | 225 |
| | Crushed aggregate | 180 | 205 | 230 | 250 |
| 20 | Uncrushed aggregate | 135 | 160 | 180 | 190 |
| | Crushed aggregate | 170 | 190 | 210 | 225 |
| 40 | Uncrushed aggregate | 115 | 140 | 160 | 175 |
| | Crushed aggregate | 155 | 175 | 190 | 205 |

(*Source: SNI 03-2834-2000*)

The slump value is between 60-180 mm, with a maximum aggregate grain size of 40 mm, the value of crushed gravel is 175 and uncrushed gravel is 205.
Free water content = 2/3 × 175 + 1/3 × 205 = 185 kg/m3

12. Cement content = 185/0.60 = 308.33 kg/m$^3$
13. Determine the percentage of fine aggregate

The percentage value of fine aggregate is obtained from the graph below. This value is obtained using known data, namely: slump value of 100 mm, cement water factor of 0.6, maximum aggregate size of 40 mm and sand zone of zone 2.

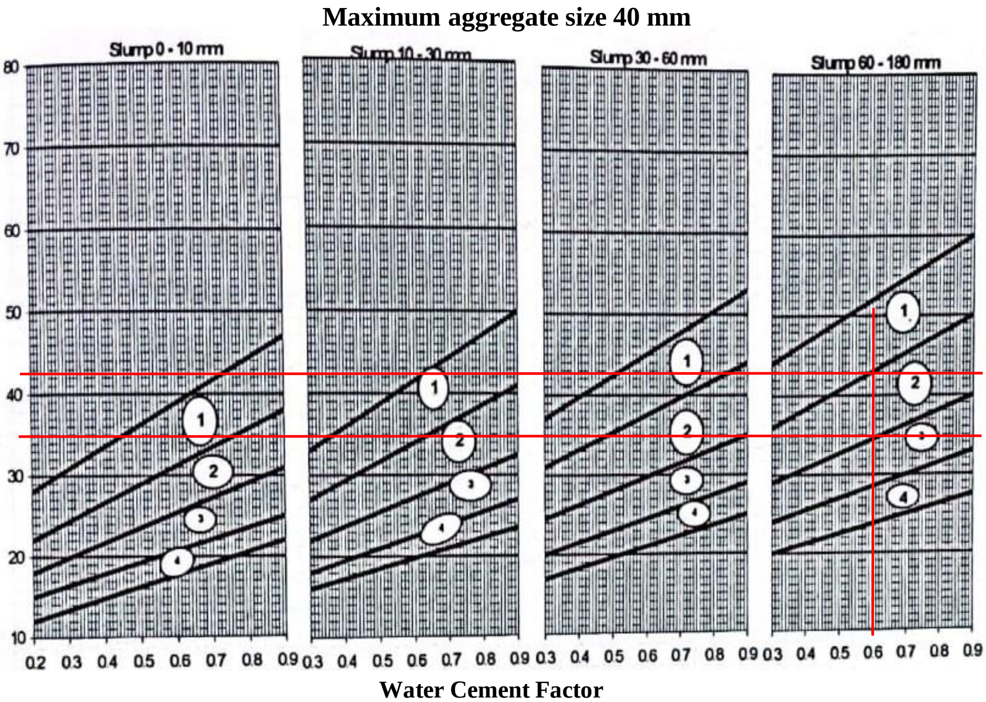



Figure 4.21 Percent of sand for a maximum grain size of 40 mm
(*Source: Mulyono, 2003*)

From the 60-180 mm slump graph, a vertical line is drawn at point 0.6 and then a horizontal line is drawn in the area of fine aggregate zone 2. Based on the results of the combined aggregate mix design, the best grade is 39% fine aggregate percentage.

### 4.3.3 Calculation of Mix Design

1. Calculation of relative density SSD

Table 4.43 Material relative density result

| Material Test Result | Fine Aggregate (%) | Coarse Aggregate (%) | Coral Reef (%) |
|---|---|---|---|
| Relative Density | 2.72 | 2.62 | 2.015 |

(*Source: Author, 2024*)

Relative density SSD = (RD fine aggregate × % fine aggregate) + (RD coarse aggregate × % coarse aggregate) + (RD coral reef aggregate × % coral reef aggregate)

a) Admixture of 0% coral reef = (2.72 × 39%) + (2.62 × 61%) + (2.015 ×65% × 0%) = 2.66

b) Admixture of 25% coral reef = (2.72 × 39%) + (2.62 × (61% - 25%×61%) + (2.015 × 25% ×61%) = 2.57

c) Admixture of 50% coral reef = (2.72 × 39%) + (2.62 × (61% - 50%×61%) + (2.015 × 50% ×61%) = 2.47

d) Admixture of 60% coral reef = (2.72 × 39%) + (2.62 × (61% - 60%×61%) + (2.015 × 60% ×61%) = 2.44

e) Admixture of 75% coral reef = (2.72 × 39%) + (2.62 × (61% - 75%×61%) + (2.015 × 75% ×61%) = 2.38

2. Calculation of concrete relative density/concrete unit weight
   The relative density of concrete is obtained from the figure below by creating a new graph with the relative density of the SSD aggregate. From the intersection point that has been made, a vertical line is drawn to show the free water content of 185 kg/m$^3$.

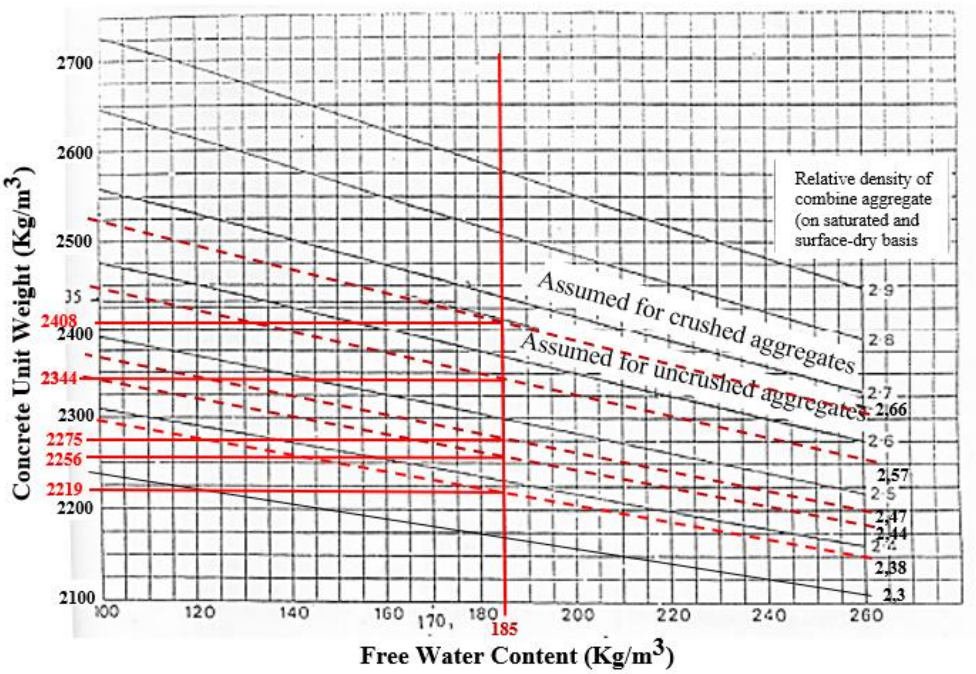



Figure 4.22 Approximate content weight of finished compacted wet concrete (*Source: SNI 03-2834-2000*)

a) Concrete unit weight of 0% coral reef admixture = 2408 kg/m$^3$
b) Concrete unit weight of 25% coral reef admixture = 2344 kg/m$^3$
c) Concrete unit weight of 50% coral reef admixture = 2275 kg/m$^3$
d) Concrete unit weight of 60% coral reef admixture = 2256 kg/m$^3$
e) Concrete unit weight of 75% coral reef admixture = 2219 kg/m$^3$

3. Calculation of combine aggregate, sand, gravel and coral reef
   - Calculation of combine aggregate weight = concrete unit weight – cement content – water content
     a) Admixture of 0% coral reef = 2408 – 308.33 – 185 = 1914.67 kg/m$^3$
     b) Admixture of 25% coral reef = 2344 – 308.33 – 185 = 1850.67 kg/m$^3$
     c) Admixture of 50% coral reef = 2275 – 308.33 – 185 = 1781.67 kg/m$^3$
     d) Admixture of 60% coral reef = 2256 – 308.33 185 = `1762.67 kg/m$^3$
     e) Admixture of 75% coral reef = 2219 – 308.33 - 185 = 1725.67 kg/m$^3$
   - Calculation of fine aggregate = % fine aggregate× combine aggregate
     a) Admixture of 0% coral reef = 39% × 1914.67 = 746.72 kg/m$^3$
     b) Admixture of 25% coral reef = 39% × 1850.67 = 721.76 kg/m$^3$
     c) Admixture of 50% coral reef = 39% × 1781.67 = 694.85 kg/m$^3$
     d) Admixture of 60% coral reef = 39% × 1762.67 = 687.44 kg/m$^3$
     e) Admixture of 75% coral reef = 39% × 1725.67 = 673.01 kg/m$^3$

   - Calculation of coral reef aggregate = % coral reef admixture × (weight of combine aggregate – weight of fine aggregate)
     a) Admixture of 0% coral reef = 0% × (1914.67 – 746.72) = 0.00 kg/m$^3$
     b) Admixture of 25% coral reef = 25% × (1850.67 – 721.76) = 282.23 kg/m$^3$
     c) Admixture of 50% coral reef = 50% × (1781.67 – 694.85) = 543.41 kg/m$^3$
     d) Admixture of 60% coral reef = 60% × (1746.67– 687.44) = 645.14 kg/m$^3$
     e) Admixture of 75% coral reef =75% × (1725.67– 673.83) = 789.49 kg/m$^3$
   - Coarse aggregate weight calculation = aggregate combination – fine aggregate – coral reef aggregate
     a) Admixture of 0% coral reef = 19214.67 – 746.72 – 0.00 = 1167.95 kg/m$^3$
     b) Admixture of 25% coral reef =1850.67– 721.76–282.23 = 846.68 kg/m$^3$

c) Admixture of 50% coral reef =1781.67– 694.85 –543.41 = 543.41 kg/m$^3$

d) Admixture of 60% coral reef = 1746.67– 687.44– 645.14 = 430.09 kg/m$^3$

e) Admixture of 75% coral reef =1725.67– 673.87–789.49 = 263.16 kg/m$^3$

4. Actual calculation of aggregate, water and cement

Table 4.44 Result of material absorption and moisture

| Material Testing Results | Fine Aggregate (%) | Coarse Aggregate (%) | Coral Reef (%) |
|---|---|---|---|
| Absorption | 0.81 | 2.9 | 13.51 |
| Moisture | 4.82 | 0.81 | 3.2 |

(*Source: Author, 2024*)

Sand absorption – sand moisture = 0.81 – 4.82 = - 4.01%

Gravel absorption – gravel moisture = 2.9 – 0.81 = 2.09%

Coral reef absorption – coral reef moisture = 13.51 – 3.2 = 10.31%

- Correction of sand $= \frac{\text{Sand Absorption - Sand Moisture}}{100} \times$Theoretical Sand
  a) Admixture of 0% coral reef $= \frac{0.81-4.82}{100} \times 746.72 = -29.94$ kg/m$^3$
  b) Admixture of 25% coral reef $= \frac{0.81-4.82}{100} \times 721.76 = -28.94$ kg/m$^3$
  c) Admixture of 50% coral reef $= \frac{0.81-4.82}{100} \times 694.85 = -27.86$ kg/m$^3$
  d) Admixture of 60% coral reef $= \frac{0.81-4.82}{100} \times 687.44 = -27.57$ kg/m$^3$
  e) Admixture of 75% coral reef $= \frac{0.81-4.82}{100} \times 673.01 = -26.99$ kg/m$^3$
- Correction of gravel $= \frac{\text{Gravel Absorption - Gravel Moisture}}{100} \times$Theoretical Gravel
  a) Admixture of 0% coral reef $= \frac{2.9 - 0.81}{100} \times 1167.95 = 24.41$ kg/m$^3$
  b) Admixture of 25% coral reef $= \frac{2.9 - 0.81}{100} \times 846.68 = 17.70$ kg/m$^3$
  c) Admixture of 50% coral reef $= \frac{2.9 - 0.81}{100} \times 543.41 = 11.36$ kg/m$^3$
  d) Admixture of 60% coral reef $= \frac{2.9 - 0.81}{100} \times 430.09 = 8.99$ kg/m$^3$
  e) Admixture of 75% coral reef $= \frac{2.9 - 0.81}{100} \times 263.16 = 5.50$ kg/m$^3$
- Correction of coral reef $= \frac{\text{Coral Absorption - Coral Moisture}}{100} \times$ Theoretical Coral
  a) Admixture of 0% coral reef $= \frac{13.51 - 3.2}{100} \times 0 = 0.00$ kg/m$^3$
  b) Admixture of 25% coral reef $= \frac{13.51 - 3.2}{100} \times 282.23 = 29.10$ kg/m$^3$

c) Admixture of 50% coral reef = $\frac{13.51 - 3.2}{100} \times 543.41 = 56.03$ kg/m$^3$

d) Admixture of 60% coral reef = $\frac{13.51 - 3.2}{100} \times 645.14 = 66.51$ kg/m$^3$

e) Admixture of 75% coral reef = $\frac{13.51 - 3.2}{100} \times 789.49 = 81.40$ kg/m$^3$

5. Calculate aggregate requirement and water (actual)

- Fine aggregate requirement = theoretical fine aggregate weight - corrected sand weight
  a) Admixture of 0% coral reef = 746.72– (-29.94) = 776.66 kg/m$^3$
  b) Admixture of 25% coral reef =721.76– (-28.94) = 750.70 kg/m$^3$
  c) Admixture of 50% coral reef = 694.85 – (-27.86) = 722.71 kg/m$^3$
  d) Admixture of 60% coral reef = 687.44 – (-27.57) = 715.01 kg/m$^3$
  e) Admixture of 75% coral reef = 673.01– (-26.99) = 700.00 kg/m$^3$
- Gravel coarse aggregate requirement = theoretical gravel weight - corrected gravel weight
  a) Admixture of 0% coral reef = 1251.69 – (24.41) = 1143.54 kg/m$^3$
  b) Admixture of 25% coral reef = 899.28 – (18.70) = 828.99 kg/m$^3$
  c) Admixture of 50% coral reef = 577.42 – (11.36) = 532.05 kg/m$^3$
  d) Admixture of 60% coral reef = 454.14 – (8.99) = 421.10 kg/m$^3$
  e) Admixture of 75% coral reef = 278.96 – (5.50) = 257.66 kg/m$^3$
- Coral reef requirement = theoretical coral reef weight – corrected coral reef weight
  a) Admixture of 0% coral reef = 0 - 0 = 0 kg/m$^3$
  b) Admixture of 25% coral reef = 282.23 – (29.10) = 253.13 kg/m$^3$
  c) Admixture of 50% coral reef = 543.41 – 56.03) = 487.38 kg/m$^3$
  d) Admixture of 60% coral reef = 645.14 – (66.51) = 578.62 kg/m$^3$
  e) Admixture of 75% coral reef = 789.49 – (81.40) = 708.10 kg/m$^3$
- Water requirement = theoretical water weight + corrected sand + corrected gravel + corrected coral reef
  a) Admixture of 0% coral reef = 185 + (-29.94) + 24.41 + 0.00 = 179.47 kg/m$^3$
  b) Admixture of 25% coral reef = 185 + (-28.94) + 17.70 + 29.10 = 202.85 kg/m$^3$
  c) Admixture of 50% coral reef =185 + (-27.86) + 11.36+ 56.03 = 224.52 kg/m$^3$
  d) Admixture of 60% coral reef = 185 + (-27.57) + 8.99 + 66.51 = 232.94 kg/m$^3$
  e) Admixture of 75% coral reef = 185 + (-26.99) + 5.50 + 81.40 = 244.91 kg/m$^3$

6. Control of concrete admixture
   Water + sand + gravel + coral reef (before adjustment) = water + sand + gravel + coral reef (after adjustment)
   a) Coral reef admixture 0%
      185 + 746.72 + 1167.95 + 0.00 = 179.47 +776.66 + 1143.54 + 0.00
      2099.67 = 2099.67 (ok)
   b) Coral reef admixture 25%
      185 + 721.76 + 846.68 +282.23 = 202.85 + 750.70+828.99+ 253.13
      2035.67 = 2035.67 (ok)
   c) Coral reef admixture 50%
      185 + 694.85 + 543.41 +543.41 = 224.52 + 722.71+532.05+487.38
      1966.67 = 1966.67 (ok)
   d) Coral reef admixture 60%
      185 + 687.44 + 430.09 + 645.14 = 232.94+715.01+421.10+ 578.62
      1947.67 = 1947.67 (ok)
   e) Coral reef admixture 75%
      185 + 673.01 + 263.16 + 789.49 = 244.91 + 700.00+257.66+708.10
      1910.66 = 1910.67 (ok)

7. Calculate volume of specimen

   **Test Specimen 10 x 20 cm**

   Volume of mold $= \frac{1}{4} \times \pi \times d^2 \times t = \frac{1}{4} \times \frac{22}{7} \times 10^2 \times 20 = 1571.428\ cm^3$

   Total sample = 2

   Total volume = 1571.428 × 2 = 3142.856 $cm^3$

   The safety factor = 0.3 = 3142.856 + (3142.856 × 0.3) = 4085.71 $cm^3$
   = 0.408571 $m^3$

   **Test Specimen 15 x 30 cm**

   Volume of mold $= \frac{1}{4} \times \pi \times d^2 \times t = \frac{1}{4} \times \frac{22}{7} \times 15^2 \times 30 = 5303.571\ cm^3$

   Total sample = 3

   Total volume = 5303.571 × 3 = 15910.71 $cm^3$

   The safety factor = 0.3 = 15910.71 + (15910.71 × 0.3) = 20683.93 $cm^3$
   = 0.020684 $m^3$

8. Calculate the material requirements needed in 3 test specimens with a cylindrical mold of 10 x 20 cm.
   a) Requirement of coral reef admixture 0%
      - Sand = 776.66 × 0.00408571 = 3.17 kg

- Gravel = 1143.54× 0.00408571 = 4.67 kg
- Coral Reef = 0.0× 0.00408571 = 0.00 kg
- Water = 179.47× 0.00408571 = 1.26 kg
- Cement = 308.33× 0.00408571 = 0.73 kg

b) Requirement of coral reef admixture 25%
- Sand = 750.70× 0.00408571 = 3.07 kg
- Gravel = 828.99× 0.00408571 = 3.39 kg
- Coral Reef = 253.13× 0.00408571 = 1.03 kg
- Water = 202.85× 0.00408571 = 0.83 kg
- Cement = 308.33× 0.00408571 = 1.26 kg

c) Requirement of coral reef admixture 50%
- Sand = 722.71× 0.00408571 = 2.95 kg
- Gravel = 532.05× 0.00408571 = 2.17 kg
- Coral Reef = 487.38× 0.00408571 = 1.99 kg
- Water = 224.52× 0.00408571 = 0.92 kg
- Cement = 308.33× 0.00408571 = 1.26 kg

d) Requirement of coral reef admixture 60%
- Sand = 715.01× 0.00408571 = 2.92 kg
- Gravel = 421.10× 0.00408571 = 1.72 kg
- Coral Reef = 578.62× 0.00408571 = 2.36 kg
- Water = 232.94× 0.00408571 = 0.95 kg
- Cement = 308.33× 0.00408571 = 1.26 kg

e) Requirement of coral reef admixture 75%
- Sand = 700.00× 0.00408571 = 2.86 kg
- Gravel = 257.66× 0.00408571 = 1.05 kg
- Coral Reef = 708.10× 0.00408571 = 2.36 kg
- Water = 244.91× 0.00408571 = 0.95 kg
- Cement = 308.33× 0.00408571 = 1.26 kg

Table 4.45 Material requirements of 20 x 10 cm test specimen

| Coral Reef Admixture | Aggregate | | | Water | Cement |
|---|---|---|---|---|---|
| | Sand | Gravel | Coral Reef | | |
| 0% | 3.17 | 4.67 | 0.00 | 0.73 | 1.26 |
| 25% | 3.07 | 3.39 | 1.03 | 0.83 | 1.26 |
| 50% | 2.95 | 2.17 | 1.99 | 0.92 | 1.26 |
| 60% | 2.92 | 1.72 | 2.36 | 0.95 | 1.26 |
| 75% | 2.86 | 1.05 | 2.89 | 1.00 | 1.26 |

(*Source: Author, 2024*)

9. Calculate the material requirements needed in 3 test specimens with a cylindrical mold of 30 x 15 cm.
   f) Requirement of coral reef admixture 0%
      - Sand = 776.66 × 0.020684 =16.06 kg
      - Gravel = 1143.54× 0.020684 = 15.53 kg
      - Coral Reef = 0.0× 0.020684 = 0.00 kg
      - Water = 179.47× 0.020684 = 3.71 kg
      - Cement = 308.33× 0.020684 = 6.38 kg
   g) Requirement of coral reef admixture 25%
      - Sand = 750.70× 0.020684 = 15.53 kg
      - Gravel = 828.99× 0.020684 = 17.15 kg
      - Coral Reef = 253.13× 0.020684 = 5.24 kg
      - Water = 224.52× 0.020684 = 4.20 kg
      - Cement = 308.33× 0.020684 = 6.38 kg
   h) Requirement of coral reef admixture 50%
      - Sand = 722.71× 0.020684 =14.95 kg
      - Gravel = 532.05× 0.020684 =11.00 kg
      - Coral Reef = 487.38× 0.020684 = 10.08 kg
      - Water = 224.52× 0.020684 = 4.64 kg
      - Cement = 308.33× 0.020684 = 6.38 kg
   i) Requirement of coral reef admixture 60%
      - Sand = 715.01× 0.020684 = 14.79 kg
      - Gravel = 421.10× 0.020684 = 8.71 kg
      - Coral reef = 578.62× 0.020684 = 11.97 kg
      - Water = 232.94× 0.020684 = 4.82 kg
      - Cement = 308.33× 0.020684 = 6.38 kg
   j) Requirement of coral reef admixture 75%
      - Sand = 700.00× 0.020684 = 14.48 kg
      - Gravel = 257.66× 0.020684 = 5.33 kg
      - Coral reef = 708.10× 0.020684 = 14.65 kg
      - Water = 224.91× 0.020684 = 5.07 kg
      - Cement = 308.33× 0.020684 = 6.38 kg

Table 4.46 Material requirements of 30 x 15 cm test specimen

| Coral Reef Admixture | Aggregate | | | Water | Cement |
|---|---|---|---|---|---|
| | Sand | Gravel | Coral Reef | | |
| 0% | 16.06 | 23.65 | 0.00 | 3.71 | 6.38 |
| 25% | 15.53 | 17.15 | 5.24 | 4.20 | 6.38 |
| 50% | 14.95 | 11.00 | 10.08 | 4.64 | 6.38 |
| 60% | 14.79 | 8.71 | 11.97 | 4.82 | 6.38 |
| 75% | 14.48 | 5.33 | 14.65 | 5.07 | 6.38 |

(*Source: Author, 2024*)

## 4.4 Slump Test Analysis

Slump tests are conducted on fresh concrete, with the aim of measuring the workability and uniformity of water usage in concrete.

1 Slump Test Specimen Age 14 Days

Table 4.47 Analysis of slump test specimen age 14 days

| Specimen | Initial height (cm) | Final height (cm) | Slump Value (cm) |
|---|---|---|---|
| BK0 | 30 | 20.5 | 9.5 |
| BK25 | 30 | 20 | 10 |
| BK50 | 30 | 19 | 11 |
| BK60 | 30 | 18.5 | 11.5 |
| BK75 | 30 | 18 | 12 |

(*Source: Author, 2024*)

Calculation example:

Slump value BK0 = Height of slump tool – Height of concrete after decrease

Slump value BK0 = 30 -20.5 = 9.5 cm

2 Slump Test Specimen Age 28 Days

Table 4.48 Analysis of slump test specimen age 28 days

| Specimen | Initial Height (cm) | Final Height (cm) | Slump Value (cm) |
|---|---|---|---|
| BK0 | 30 | 20 | 10 |
| BK25 | 30 | 20 | 10 |
| BK50 | 30 | 19 | 11 |
| BK60 | 30 | 18 | 12 |
| BK75 | 30 | 15 | 15 |

(*Source: Author, 2024*)

Calculation slump test is using equation 2.15:
Slump value BK0 = Height of slump tool – Height of concrete after decrease
Slump value BK0 = 30 - 20 = 10 cm

3 Average Slump Value

Table 4.49 Result of average slump value calculation

| Specimen | Slump Value | | Slump Value Average | Increase of Slump Average |
|---|---|---|---|---|
| | 14 Days | 28 Days | | |
| BK0 | 9.5 | 10 | 9.75 | 0% |
| BK25 | 10 | 10 | 10 | 3% |
| BK50 | 11 | 11 | 11 | 13% |
| BK60 | 11.5 | 12 | 11.75 | 21% |
| BK75 | 12 | 15 | 13.5 | 38% |

(*Source: Author, 2024*)

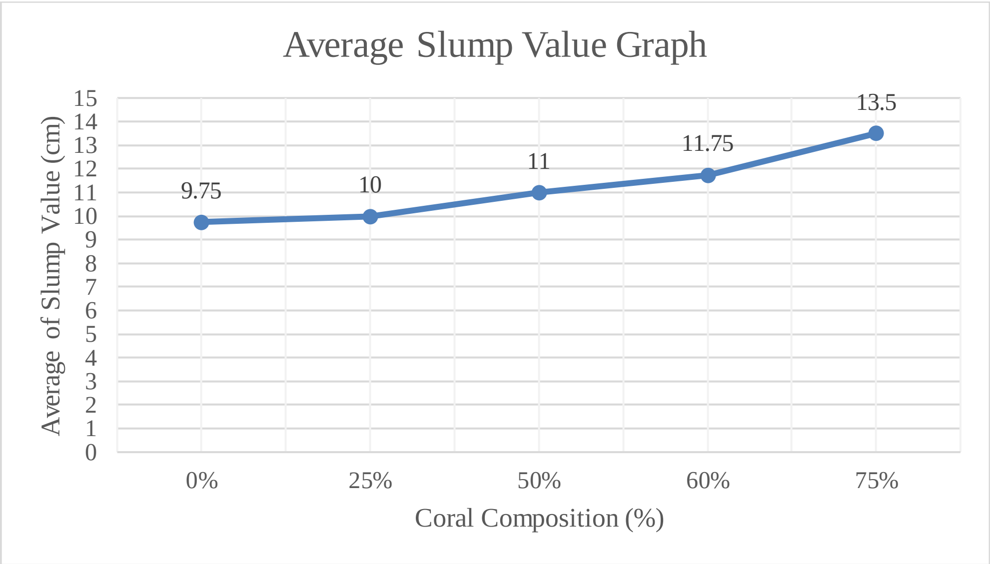



Figure 4.23 Graph of average slump value
(*Source: Author, 2024*)

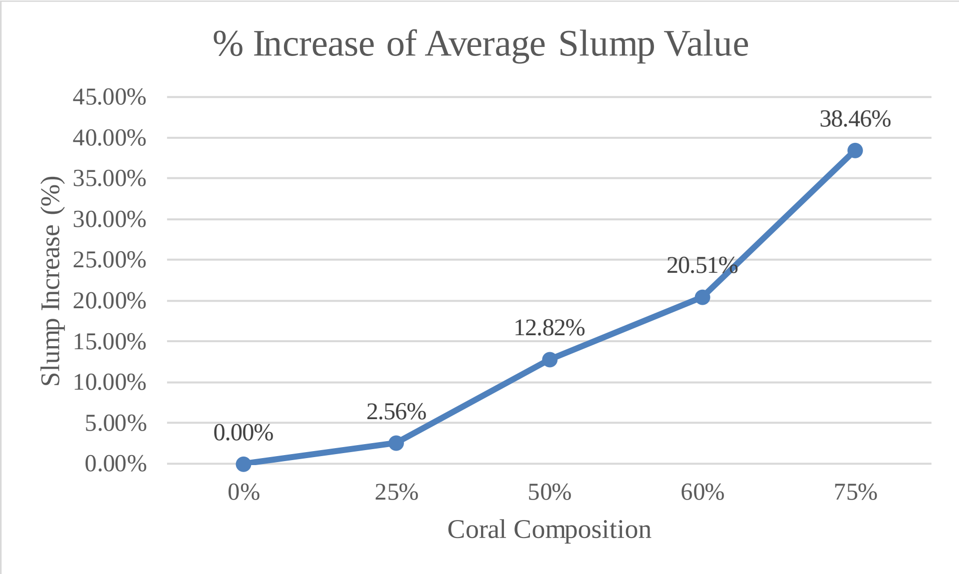



Figure 4.24 Increase of average slump value
(*Source: Author, 2024*)

The results of the concrete slump test, it can be seen that each addition of coral reefs makes the slump value higher. However, the specified slump is 7.5 cm - 15 cm and the results of the study meet the requirements. The highest slump value was obtained in the 28-day BK75 specimen, with a value of 15 cm. In this study, the addition of coral reef aggregate to the concrete mix increased the slump value due to several factors:

- Coral aggregates have a shape that tends to be round compared to crushed gravel which has an angular shape. Coral aggregate has a shape that tends to be round because the coral aggregate itself is formed due to erosion by water or the whole is formed due to displacement. The use of round-shaped coarse aggregate results in easier concrete to work with (Tjokrodimuljo, 1996). The coarse aggregate texture reduces the degree of workability, but can improve the aggregate-cement bond and compressive strength of concrete (Scribd.com/Agregat Kasar, accesed 2024).
- The coral aggregates were stored outdoors due to limited storage space, while the crushed gravel was stored indoors. This study was conducted during the rainy season, which increased the moisture content of the coral aggregate. The increased moisture content of the coral aggregate increases the amount of water in the concrete. The more water used, the easier the concrete is to work with (Tjokrodimuljo, 1996).

### 4.5 Unit Weight Analysis

Mold Weight = 10 kg

Table 4.50 Fresh concrete unit weight calculation

| Specimen | Age | Volume | Concrete + Mold | Unit Weight | Average |
|---|---|---|---|---|---|
| | Days | m³ | kg | Kg/m³ | Kg/m³ |
| BK0 | 14 | 0.005304 | 23.261 | 2500.189 | 2496.669 |
| BK0 | 14 | 0.005304 | 23.301 | 2507.730 | |
| BK0 | 14 | 0.005304 | 23.165 | 2482.089 | |
| BK0 | 28 | 0.005304 | 23.227 | 2493.778 | 2451.609 |
| BK0 | 28 | 0.005304 | 22.884 | 2429.110 | |
| BK0 | 28 | 0.005304 | 22.899 | 2431.938 | |
| BK25 | 14 | 0.005304 | 22.145 | 2289.781 | 2335.093 |
| BK25 | 14 | 0.005304 | 22.706 | 2395.551 | |
| BK25 | 14 | 0.005304 | 22.305 | 2319.947 | |
| BK25 | 28 | 0.005304 | 21.840 | 2232.278 | 2301.848 |
| BK25 | 28 | 0.005304 | 21.942 | 2251.508 | |
| BK25 | 28 | 0.005304 | 22.845 | 2421.757 | |
| BK50 | 14 | 0.005304 | 21.772 | 2219.457 | 2305.870 |
| BK50 | 14 | 0.005304 | 22.506 | 2357.843 | |
| BK50 | 14 | 0.005304 | 22.413 | 2340.309 | |
| BK50 | 28 | 0.005304 | 21.671 | 2200.415 | 2290.410 |
| BK50 | 28 | 0.005304 | 22.165 | 2293.552 | |
| BK50 | 28 | 0.005304 | 22.609 | 2377.262 | |
| BK60 | 14 | 0.005304 | 21.422 | 2153.469 | 2244.407 |
| BK60 | 14 | 0.005304 | 22.233 | 2306.373 | |
| BK60 | 14 | 0.005304 | 22.058 | 2273.379 | |
| BK60 | 28 | 0.005304 | 21.569 | 2181.184 | 2269.796 |
| BK60 | 28 | 0.005304 | 21.924 | 2248.115 | |
| BK60 | 28 | 0.005304 | 22.624 | 2380.090 | |
| BK75 | 14 | 0.005304 | 21.335 | 2137.066 | 2135.307 |
| BK75 | 14 | 0.005304 | 21.430 | 2154.977 | |
| BK75 | 14 | 0.005304 | 21.212 | 2113.876 | |
| BK75 | 28 | 0.005304 | 21.593 | 2185.709 | 2141.088 |
| BK75 | 28 | 0.005304 | 21.500 | 2168.175 | |
| BK75 | 28 | 0.005304 | 20.976 | 2069.382 | |

(*Source: Author, 2024*)

Calculation example: Specimen BK01, the calculation uses equation 2.16

$M_c$ = 23.261

$M_m$ = 10.000

$V_m$ = 0.005304

$$D = \frac{M_c - M_m}{V_m}$$

$$D = \frac{23.261 - 10.000}{0.005304} = \frac{13.261}{0.005304} = 2500.189 \text{ kg/m}^3$$

Table 4.51 Calculation of average fresh concrete unit weight

| Specimen | SNI 03-2847-2002 | Average Unit Weight | Percentage Decrease | Description |
|---|---|---|---|---|
| BK0 | 2200-2500 | 2474.139 | 0.00% | Qualified |
| BK25 | 2200-2500 | 2318.470 | 6.29% | Qualified |
| BK50 | 2200-2500 | 2298.140 | 7.11% | Qualified |
| BK60 | 2200-2500 | 2257.102 | 8.77% | Qualified |
| BK75 | 2200-2500 | 2138.198 | 13.58% | Unqualified |

(*Source: Author, 2024*)

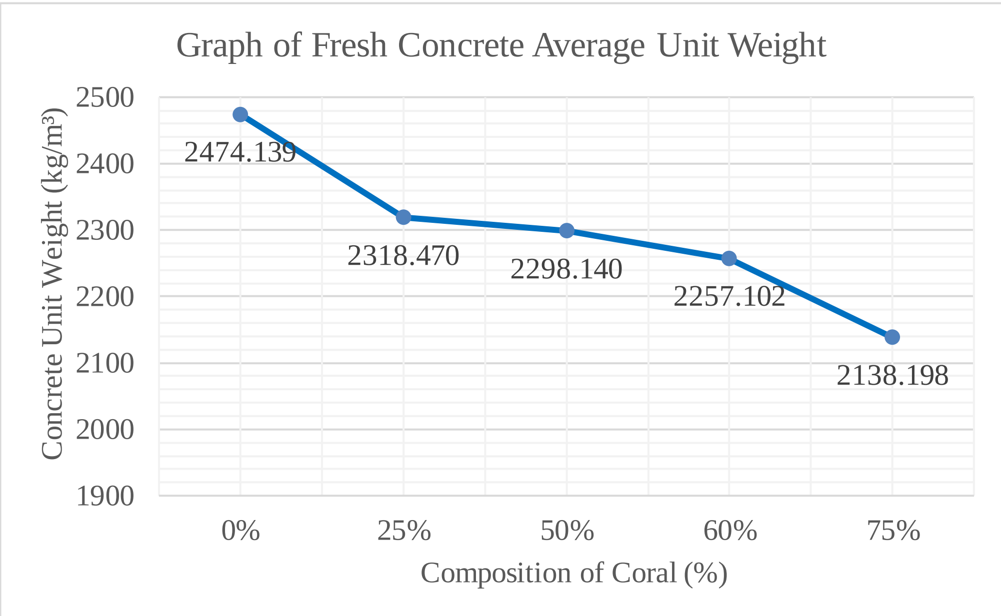



Figure 4.25 Graph of fresh concrete average unit weight

(*Source: Author, 2024*)

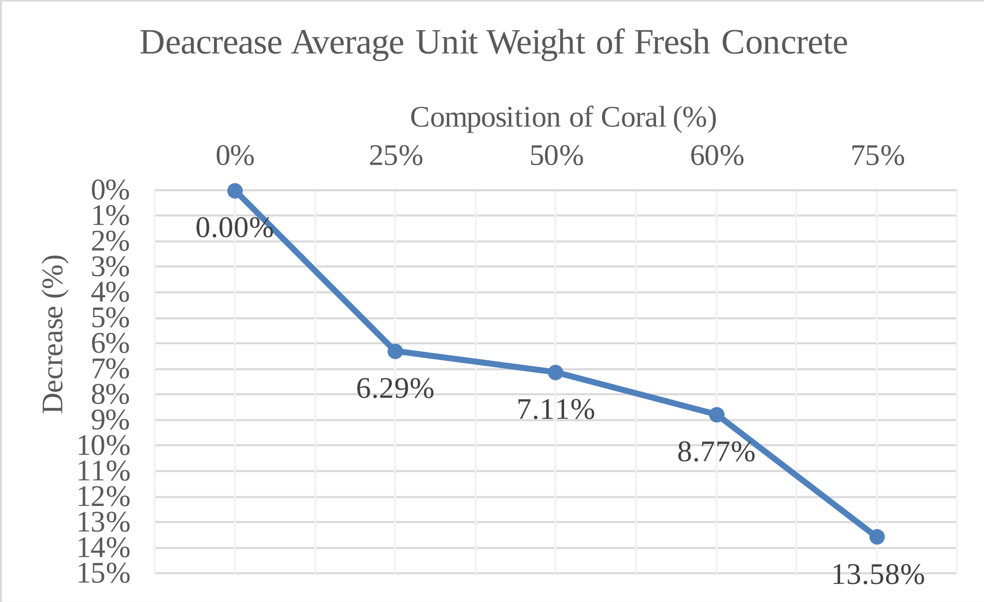



Figure 4.26 Graph of decrease fresh concrete average unit weight
(*Source: Author, 2024*)

In testing the unit weight of fresh concrete, at 0%, 25%, 50%, 60% coral reefs composition, the unit weight values obtained are 2474.139 kg/m$^3$, 2318.470 kg/m$^3$, 2298.140 kg/m$^3$, 2257.102 kg/m$^3$, the weight content of concrete meets the requirements of SNI 03-2847-2002 where the weight content of normal concrete has a value of 2200-2500 kg/m3. At 75% coral reefs composition with an average content weight of 2135.307 kg/m3 does not meet the normal concrete content weight based on SNI 03-2847-2002, but this value is close to the normal concrete content weight.

In this research, it is concluded that the replacement of crushed gravel with coral aggregate make a decrease in unit weight of concrete, this is accordance with research Wesli et al. (2023). In this study, the decrease in the weight of concrete contents with increasing composition of coral aggregate is due to the fact that coral aggregate has a lighter relative density and volume weight compared to the relative density of crushed gravel, this is in accordance with research Widyawati (2011) the thing that makes concrete light is the specific gravity of concrete and the light volume weight of concrete. The large number of pores in the coral aggregate also affects the specific gravity of the concrete, the coral aggregate makes the concrete have many air voids in it, therefore, the density of the concrete decreases.

## 4.6 Water Absorption Analysis

Table 4.52 Water absorption value, age 28 days

| No. | Specimen | SSD Concrete Weight (gram) | Dry Weight (gram) | Water Absorption (% | Average (%) |
|---|---|---|---|---|---|
| 1 | BK0 | 3814 | 3646 | 4.608 | 4.381 |
| 2 | BK0 | 3861 | 3707 | 4.154 | |
| 3 | BK25 | 3791 | 3616 | 4.840 | 5.399 |
| 4 | BK25 | 3681 | 3474 | 5.959 | |
| 5 | BK50 | 3609 | 3420 | 5.526 | 5.474 |
| 6 | BK50 | 3675 | 3486 | 5.422 | |
| 7 | BK60 | 3473 | 3214 | 8.058 | 9.290 |
| 8 | BK60 | 3393 | 3070 | 10.521 | |
| 9 | BK75 | 3319 | 2961 | 12.091 | 12.067 |
| 10 | BK75 | 3349 | 2989 | 12.044 | |

(*Source: Author, 2024*)

Calculation of water absorption carried out by using equation 2.17

Calculation Example: BK0

B = 3814

A = 3646

$$\text{Absorption} = \left(\frac{B-A}{A}\right) \times 100\%$$

$$\text{Absorption} = \left(\frac{3814 - 3646}{3646}\right) \times 100\% = 4.60\ \%$$

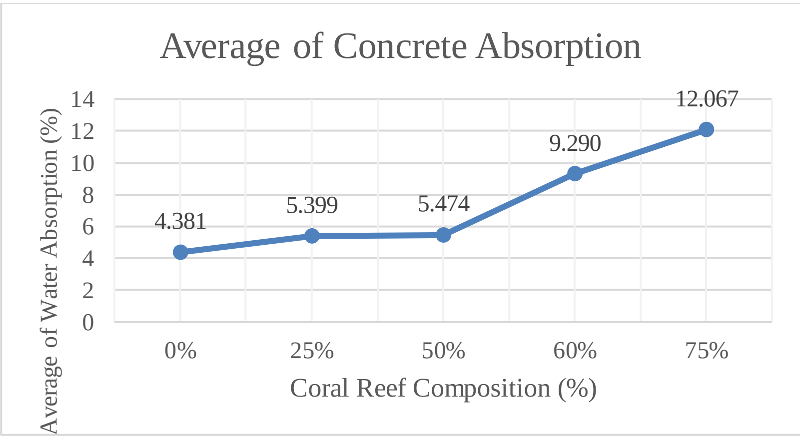



Figure 4.27 Graph of Average water absorption concrete

(*Source: Author, 2024*)

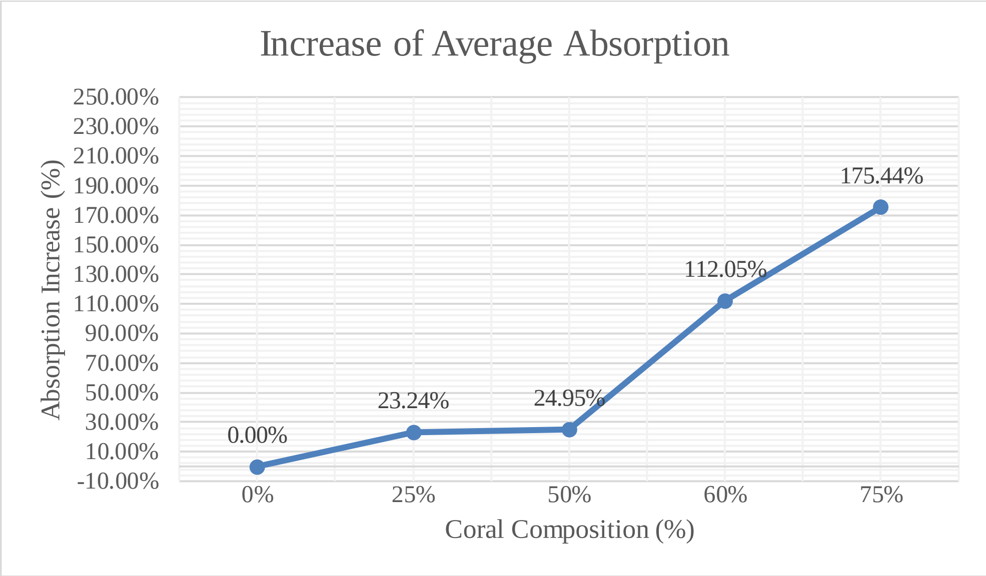



Figure 4.28 Increase of Average absorption
(*Source: Author, 2024*)

From the results of the concrete water absorption test, it can be seen that the addition of coral aggregate makes the absorption value increase. The maximum water absorption value of concrete is in the BK75 specimen of 12.067%. Based on SNI 03-2914-1992, the maximum value of water absorption in test specimens-soaked 1×24 hours are 6.5%. In this research, the qualified absorption value is in the mixture of 0%, 25%, and 50% coral reef aggregate.

Based on Wang et al. (2023), corals have the disadvantage of high-water-absorption. In this research, the coral aggregate used has many voids or pores, resulting in greater porosity of the concrete. The voids or pores of the coarse aggregate absorb the water that surrounds it (Sultan et al., 2018). High porosity aggregate affects the absorption value of concrete because it covers 70% of the weight of concrete, thus making concrete have a high absorption value (Widyawati, 2011).

## 4.7 Compressive Strength Analysis

Table 4.53 Concrete Compressive Strength Analysis

| Specimen | Age Days | Area ($mm^2$) | Pressure (kg) | Pressure (N) | Compressive Strength ($N/mm^2$) | Average ($N/mm^2$) |
|---|---|---|---|---|---|---|
| BK0 | 14 | 17678.57 | 18500 | 181423.03 | 10.262 | 10.355 |
| BK0 | 14 | 17678.57 | 19500 | 191229.68 | 10.817 | |
| BK0 | 14 | 17678.57 | 18000 | 176519.70 | 9.985 | |
| BK0 | 28 | 17678.57 | 22983 | 225386.24 | 12.749 | 12.371 |
| BK0 | 28 | 17678.57 | 22472 | 220375.04 | 12.466 | |
| BK0 | 28 | 17678.57 | 21450 | 210352.64 | 11.899 | |
| BK25 | 14 | 17678.57 | 17079 | 167487.78 | 9.474 | 9.537 |
| BK25 | 14 | 17678.57 | 17500 | 171616.38 | 9.708 | |
| BK25 | 14 | 17678.57 | 17000 | 166713.05 | 9.430 | |
| BK25 | 28 | 17678.57 | 18500 | 181423.03 | 10.262 | 10.355 |
| BK25 | 28 | 17678.57 | 18500 | 181423.03 | 10.262 | |
| BK25 | 28 | 17678.57 | 19000 | 186326.35 | 10.540 | |
| BK50 | 14 | 17678.57 | 13000 | 127486.45 | 7.211 | 8.598 |
| BK50 | 14 | 17678.57 | 20000 | 196133.00 | 11.094 | |
| BK50 | 14 | 17678.57 | 13500 | 132389.78 | 7.489 | |
| BK50 | 28 | 17678.57 | 17000 | 166713.05 | 9.430 | 10.077 |
| BK50 | 28 | 17678.57 | 18000 | 176519.70 | 9.985 | |
| BK50 | 28 | 17678.57 | 19500 | 191229.68 | 10.817 | |
| BK60 | 14 | 17678.57 | 15000 | 147099.75 | 8.321 | 8.598 |
| BK60 | 14 | 17678.57 | 17500 | 171616.38 | 9.708 | |
| BK60 | 14 | 17678.57 | 14000 | 137293.10 | 7.766 | |
| BK60 | 28 | 17678.57 | 14000 | 137293.10 | 7.766 | 9.523 |
| BK60 | 28 | 17678.57 | 17500 | 171616.38 | 9.708 | |
| BK60 | 28 | 17678.57 | 20000 | 196133.00 | 11.094 | |
| BK75 | 14 | 17678.57 | 12000 | 117679.80 | 6.657 | 8.043 |
| BK75 | 14 | 17678.57 | 14000 | 137293.10 | 7.766 | |
| BK75 | 14 | 17678.57 | 17500 | 171616.38 | 9.708 | |
| BK75 | 28 | 17678.57 | 15000 | 147099.75 | 8.321 | 8.413 |
| BK75 | 28 | 17678.57 | 16000 | 156906.40 | 8.876 | |
| BK75 | 28 | 17678.57 | 14500 | 142196.43 | 8.043 | |

(*Source: Author, 2024*)

Calculation of compressive strength is using equation 2.18
Calculation of specimen BK01

$$\text{Concrete compressive strength} = \frac{P}{A}$$

$$\text{Concrete compressive strength} = \frac{181423.03}{17678.57}$$

Concrete compressive strength = 10.262 $N/mm^2$

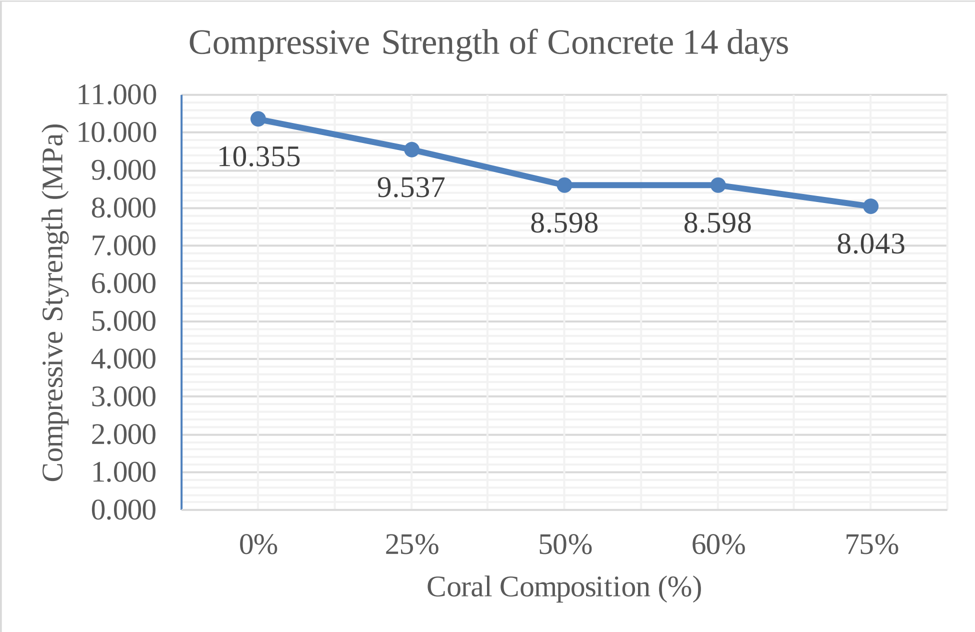



Figure 4.29 Graph of concrete compressive strength age 14 days
(*Source: Author, 2024*)

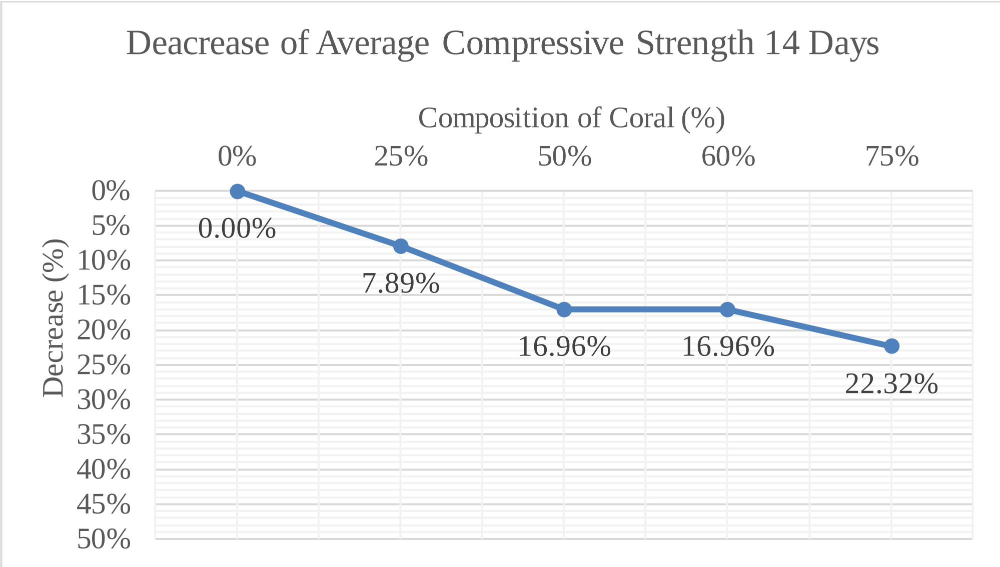



Figure 4.30 Graph of decrease compressive strength age 14 days
(*Source: Author, 2024*)

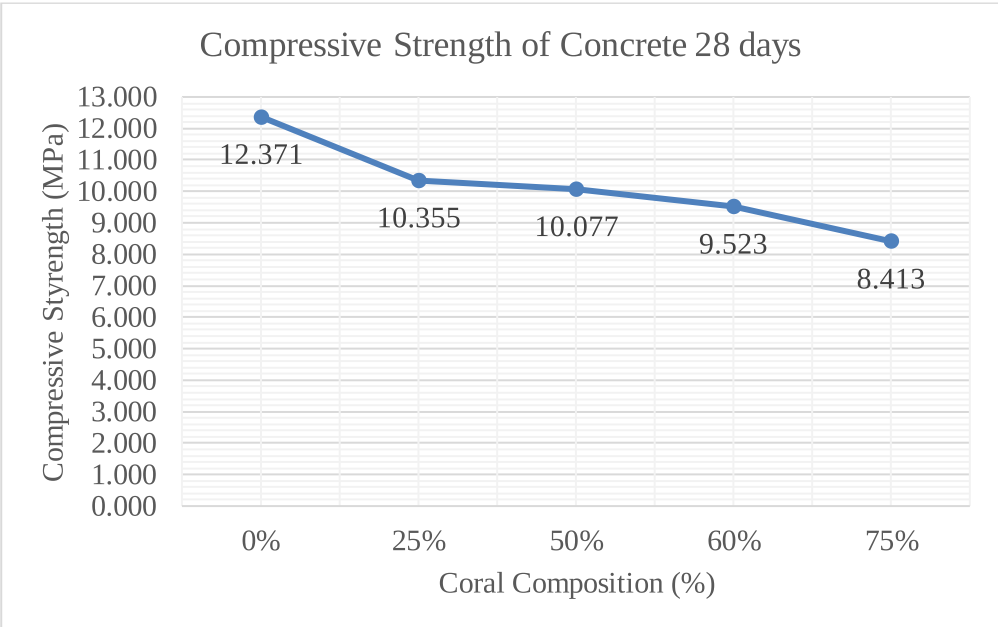



Figure 4.31 Graph of concrete compressive strength age 28 days
(*Source: Author, 2024*)

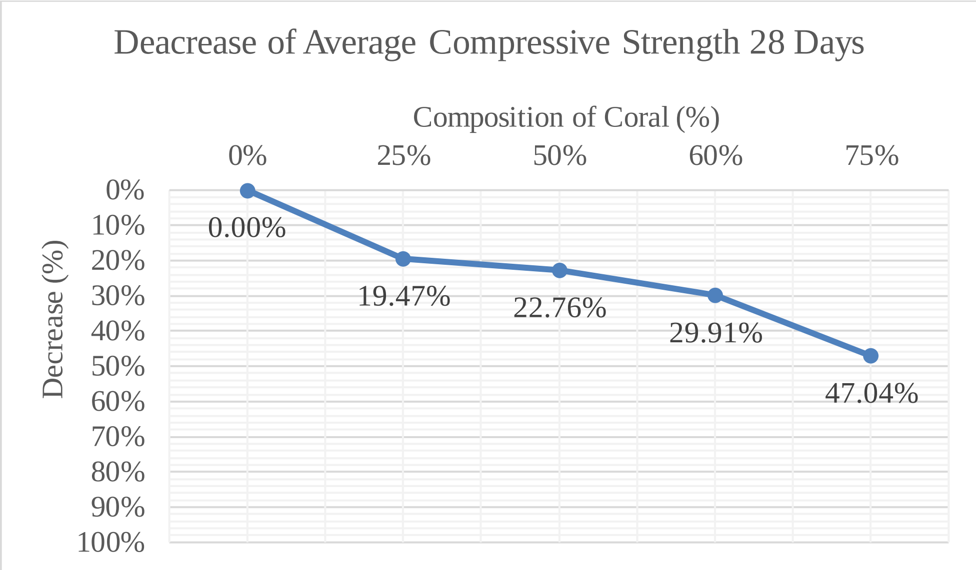



Figure 4.32 Graph of decrease concrete compressive strength age 28 days

(*Source: Author, 2024*)

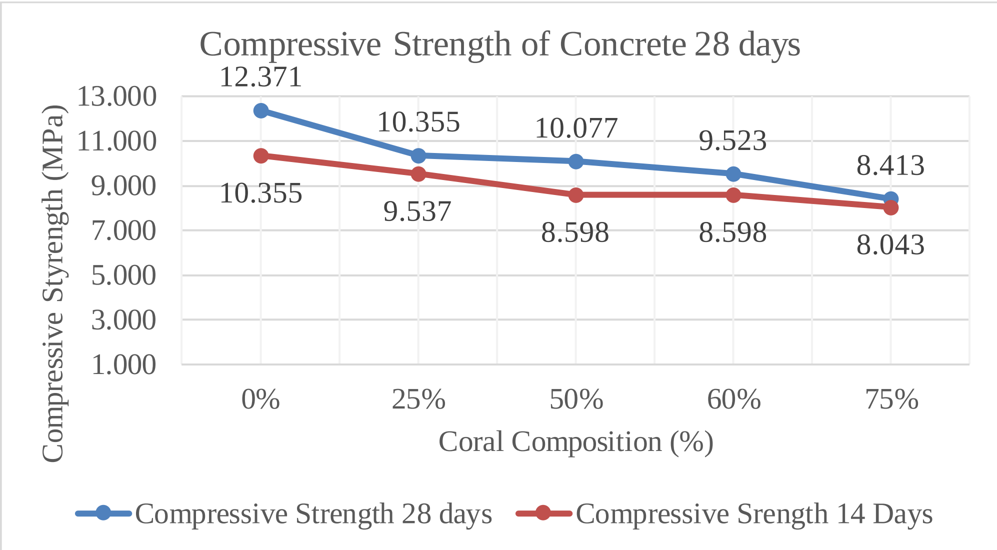



Figure 4.33 Graph of concrete compressive strength age 14 and 28 days

(*Source: Author, 2024*)

From the results of the concrete compressive strength test, it can be seen that the resulting concrete compressive strength does not meet the target compressive strength of 14.5 MPa. The average compressive strength of 0% coral reefs is 12.371 MPa, at the age of 28 days, with the compressive strength value of each test specimen

1, 2, 3 sequentially equal to 11.899 MPa, 12.466 MPa, and 12.749 MPa. From these values it can be concluded that normal concrete without a mixture of coral reef meets the requirements. While concrete with the replacement of coral reefs as aggregate composition of 25%, 50%, 60%, and 75% does not meet the requirements and experienced a decrease in compressive strength with a sequential average compressive strength value of 10.355 MPa, 10.077 MPa, 9.523 MPa, and 8.413 MPa. From these compressive strength values, based on Kementrian PUPR (2019) the 25% and 50% concrete coral compositions meet the requirements of non-structural concrete used as a working floor and concrete backfill material (10 MPa ≤ f'c < 15 MPa). From the results of the study, it was concluded that the replacement of gravel using coral reefs made the concrete experience a decrease in concrete compressive strength, this is in accordance with research conducted by Wesli et al. ( 2023) dan Wang et al. (2023).

Based on Wang et al. (2023), coral has the disadvantage of high porosity. Porosity is the percentage of pores in aggregate or concrete. In this study, it was found that the greater the use of aggregates containing pores in concrete, the lower the compressive strength of the concrete, which is in accordance with the research conducted by Shandy & Hermanto (2019). Increasing the percentage of coarse coral aggregate makes the concrete decrease linearly, this is in accordance with the research conducted by Wang et al. (2023). The decrease in compressive strength of concrete using coral aggregate is due to the poorer characteristics of coral aggregate compared to crushed gravel. The characteristics of coral aggregate that make the quality of concrete decrease are:

- Coral aggregate has a smaller relative density than crushed gravel, and a higher absorption value than crushed gravel. The greater the specific gravity of the aggregate, the higher the water absorption, indicating that the aggregate grains are denser and stronger (Sulistyawati, 2009). The relative density of the aggregate also affects the abrasion value of the aggregate, where the smaller the relative density of the aggregate, the greater the abrasion value.
- Coral aggregate affects the water absorption value of concrete because coral aggregate has a high porosity and absorption value. The large number of voids in the coral aggregate results in a large number of voids in the concrete. The correlation between porosity and compressive strength is that the greater the porosity in the test specimen, the lower the strength of the concrete (Sultan et al., 2018).
- The shape of coral aggregates tends to be more rounded than that of angular crushed gravel. Concrete with rounded aggregates has less strong intergranular bonds, whereas concrete with angular coarse aggregates has good or strong intergranular bonds (Tomayahu, 2016).

- Silt content of the coral aggregate. Materials that contain a lot of mud or dust should be avoided because the grains are so fine that they have less hardness. The hardness of the filler material will affect the hardness of the concrete (Joni, 2011).

### 4.7.1 Factors Affecting The Strength that Does Not Reach The Target

From the results of the concrete compressive strength test, it can be seen that the resulting concrete compressive strength does not meet the desired compressive strength of 14.5 MPa. The compressive strength did not reach the plan quality in this study may be due to several factors:

- The grade of the coarse aggregate used is not well distributed.
  A good aggregate to use in concrete is one in which all grain sizes are well distributed, called a continuous grade aggregate. Well-distributed aggregates create small pore numbers and high compressibility, leading to good interlocking. Concrete will produce dense, high quality concrete if it is made from materials that have good aggregate grade (Joni, 2011). Based on research Bangki (2020), Concrete using continuous aggregates has a higher compressive strength than concrete using uniform aggregates.
- How to compact concrete
  In this study, the compaction of concrete was carried out by means of corners. With this way will obtain limited density result, therefore that the quality of concrete is also limited, the denser the concrete, the higher the quality. Concrete compaction using cornering makes the grains shake their balance so that they move one against the other looking for a new denser balance. (Joni, 2011). Compaction is recommended using a vibrating needle or vibrating harmer (formwork). This method produces greater energy and higher compaction power, resulting in better concrete.

### 4.7.2 Evaluation and Acceptance of Unsatisfactory Compressive Strength

In this section, the decision to accept concrete with unsatisfactory compressive strength is explained. Based on SNI 2847-2013:

- the average compressive strength of the 3 core concretes is ≥ 85% of the f'c
- And none of the core concretes had compressive strength < 75% of f’c.

By using the f’c = 14.5 MPa, then 85% f’c = 12.325 MPa and 75% f’c = 10.875 MPa. The average compressive strength of 0% coral reefs is 12.371 MPa, at the age of 28 days, with the compressive strength value of each test specimen 1, 2, 3 sequentially equal to 11.899 MPa, 12.466 MPa, and 12.749 MPa. It is concluded that normal concrete quality is considered eligible.

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