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Studi Mikrostruktur Agregat Lokal Fakfak Menggunakan SEM-EDS: Implikasi Terhadap Ketahanan Beton Modern

Microstructural Study Of Fakfak Local Aggregates Using Sem-EDS: Implications For The Durability Of Modern Concrete

Aqilah Attamimi[a]*, Imran[b]
Politeknik Negeri Fakfak[a,b]
[a]aqilah@polinef.id, [b]imran@polinef.id

Abstract
This study investigates the properties of Fakfak local aggregates and explores their potential use in concrete applications. The aggregates were characterized using Scanning Electon Microscopy (SEM) to asses they chemical composition and microstructural features. The SEM analysis showed notable porosity and microcracks, indicating potential weaknesses. The results revealed that Fakfak local Aggregates exhibit porous morphologies with a considerable calcium (CaO) content. Such differences in elemental composition and morphology have significant implications for concrete durability. The findings highlight that aggregates containing CaO and adequate surface porosity promote calcite precipitation and provide pore spaces that facilitate crack healing. Accordingly, this kind of Aggregates demonstrate greater potential as concrete admixtures, and also offering promising prospects for enhancing the durability and self-healing capacity of modern concrete. Despite these challenges, the study suggests that with appropriate treatments, such as the use of supplementary cementious materials these aggregates could be effectively utilized in concrete, contributing to sustainable construction pratices. The findings underscore the importance of targeted reinforcement strategies to enhance aggregate performance and recommend further research on long-term durability and environmental impacts.
Keywords: *Local Agregat, Fakfak, SEM, Concrete*

Abstrak
Penelitian ini mengkaji sifat-sifat agregat lokal Fakfak dan mengeksplorasi potensi penggunaannya dalam aplikasi beton. Agregat tersebut dianalisis menggunakan Mikroskop Elektron Pemindaian (SEM) untuk mengevaluasi komposisi kimia dan fitur mikrostrukturnya. Analisis SEM menunjukkan porositas yang signifikan dan retakan mikro, yang mengindikasikan potensi kelemahan. Hasil penelitian menunjukkan bahwa agregat lokal Fakfak memiliki morfologi poros dengan kandungan kalsium (CaO) yang cukup tinggi. Perbedaan dalam komposisi unsur dan morfologi ini memiliki implikasi signifikan bagi ketahanan beton. Temuan ini menyoroti bahwa agregat yang mengandung CaO dan porositas permukaan yang memadai mendorong presipitasi kalsit dan menyediakan ruang pori yang memfasilitasi penyembuhan retak. Oleh karena itu, jenis agregat ini menunjukkan potensi yang lebih besar sebagai aditif beton, serta menawarkan prospek menjanjikan untuk meningkatkan ketahanan dan kemampuan penyembuhan diri beton modern. Meskipun terdapat tantangan ini, studi ini menyarankan bahwa dengan perlakuan yang tepat, seperti penggunaan bahan semen tambahan, agregat ini dapat dimanfaatkan secara efektif dalam beton, berkontribusi pada praktik konstruksi berkelanjutan. Temuan ini menekankan pentingnya strategi penguatan yang ditargetkan untuk meningkatkan kinerja agregat dan merekomendasikan penelitian lebih lanjut mengenai ketahanan jangka panjang dan dampak lingkungan.
Kata Kunci: Agregat Lokal, Fakfak, SEM, Beton

1. Introduction

The population growth rate in West Papua Province continues to increase steadily. This has resulted in rapid and inevitable regional development. The rising population reflects a significant increase in human activities, which directly accompanies the need for adequate infrastructure to support societal functions. The demand for materials for infrastructure development has grown year by year, in line

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with increasing public expectations for infrastructure services in daily mobility. The problem lies in certain areas where the availability of materials meeting standard specifications is very limited or even nonexistent, necessitating supply from other regions. This situation leads to substantially higher construction costs and extended project durations.

Aggregates account for approximately 70–80% of the volume in concrete composition, significantly influencing all concrete properties, particularly its strength (Neville, 1995). Consequently, it is anticipated that the aggregates used will have a substantial effect on concrete properties (Thomas & Folliard, 2007). The type of aggregate is crucial for achieving the desired quality of concrete. Using aggregates with different textural properties, even with cement of the same quality, can result in variations in concrete behavior (Yılmaz & Tuğrul, 2012) Aggregates can affect all concrete properties and can also limit its strength (Güçlüer, 2021). Furthermore, (Kim et al., 2019) observed that using aggregates from different origins influences concrete strength.

By his researchs (Poon & Lam, 2008) determined that the physical and mechanical properties of prefabricated elements produced from various types of aggregates vary according to the aggregate type. As investigated by (Zhang et al., 2023), aggregate properties have been found to be the most dominant factor affecting the mechanical properties of porous concrete due to the effectiveness of coarse aggregates in forming the skeletal structure. The mechanical properties of concrete mixtures are highly influenced by the fraction and characteristics of the aggregates, as aggregates constitute the majority of the mixture—more than 80% by volume and approximately 95% by mass. The physical and mechanical performance of the mixture is strongly affected by the geometric morphology of aggregate particles and the interlocking between particle sizes (Wang et al., 2016).

SEM-EDS is a highly essential and adaptable characterization technique, allowing comprehensive 2D spatial analysis of microstructural features within heterogeneous cement-based materials (Li et al., 2025). Despite its widespread use, the relationship between the microstructural characteristics of fakfak local aggregates and its mechanical properties is not fully understood, particularly in the context of construction applications. There is limited research on how specific microstructural features, such as grain size and porosity, influence the mechanical performance of fakfak local aggregates in real world constructions scenarios. While SEM has been used to characterize various materials, its application in systematically enhancing the mechanical properties of fakfak local aggregates for construction purposes remains underexplored.

A more specific investigation into the physical, mechanical, and chemical suitability of local aggregates in West Papua Province can have a positive impact on communities, particularly in Fakfak Regency. This research allows for a detailed assessment of the potential of local aggregates and can serve as a basis for reducing reliance on imported construction materials in the future.

This study aims to employ SEM-EDS to comprehensively characterize the chemical composition, and microstructural features of Fakfak local aggregates. By understanding these characteristics, we can identify the key factors that affect the mechanical properties and potential for modern concrete reinforcement. The hypothesis is that targeted reinforcement strategies based on detailed characterization can improve the performance of local aggregates in concrete

applications. Enhancing the mechanical properties of local aggregates can lead to more sustainable construction practices by utilizing locally available materials that might otherwise be considered waste. Improved understanding of the material properties will contribute to the development of more durable and cost effective construction materials, reducing the environmental impact of construction activities. The findings could inform industry standards and guidelines, promoting the use of optimalized fakfak local aggregates in various constructions applications.

2. Method

The aggregates were sourced from several quarries in Fakfak Regency, West Papua, Indonesia. The aggregate samples were crushed and sieved to produce coarse aggregates with sizes of 1-2 cm and 2-3 cm. The aggregates were taken from three different quarries and named aggregates A, B, and C. The objective of this study was to examine the microstructural features of fakfak local aggregates, including rain size, porosity, and surface morphology. To achieve this, samples were coated with a thin layer of gold to enhance concutivity and analized using SEM microscope. SEM images were captured at various magnifications to assess microstructural characteristics, energy-dispersive X-ray spectroscopy (EDS) was used in conjuction with SEM to provide elemental mapping.

3. Result and Discussion

SEM images revealed a heterogeneous microstructure characterized by varying grain sizesand significant porosity. The grain boundaries appeared irregular, and some microcracks were observed.

Scanning Electron Microscopy (SEM) Coarse Aggregate A

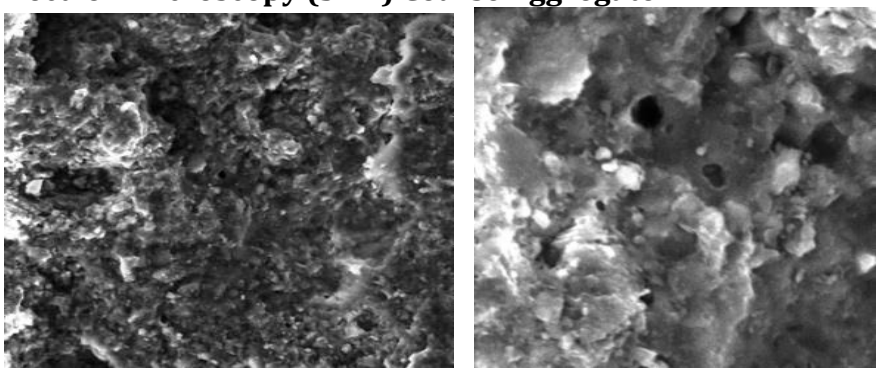

Figure 1. SEM Results of coarse aggregate sample A

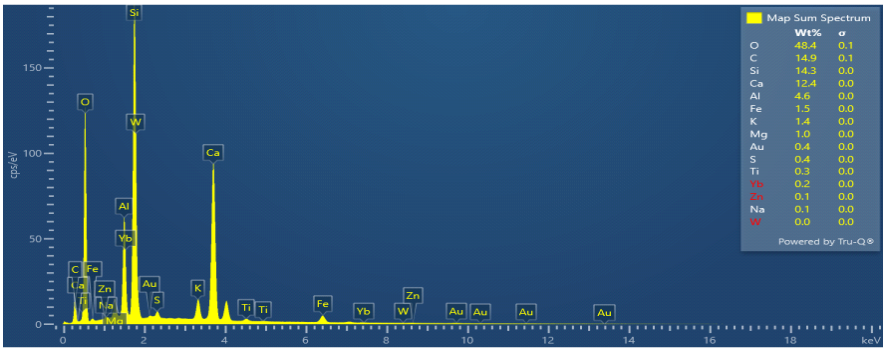

Figure 2. SEM Spektrum Results of coarse aggregate sample A

The EDS spectrum revealed dominant elemental constituents, namely Oxygen (O, 48.4%), Carbon (C, 14.9%), Silicon (Si, 14.3%), and Calcium (Ca, 12.4%). These findings suggest that the material predominantly comprises silicate- and calcium-based compounds. SEM-EDS characterization of Aggregate A further demonstrated a microstructure dominated by O, C, Si, and Ca, exhibiting a porous morphology with irregular granular features and a brittle nature.

Scanning Electron Microscopy (SEM) Coarse Aggregate B

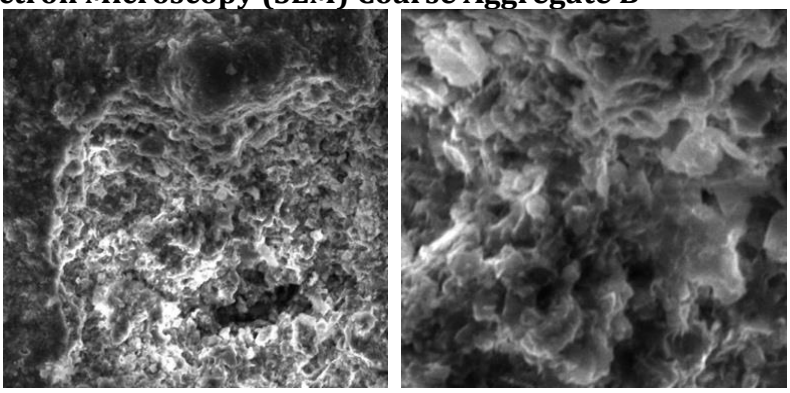

Figure 3. SEM Results of coarse aggregate sample B

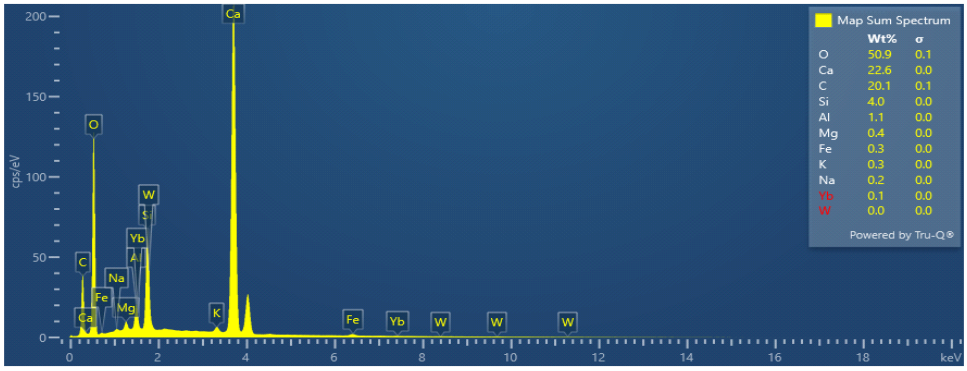

Figure 4. SEM Spektrum Results of coarse aggregate sample B

Based on the SEM and EDS results, the analyzed sample exhibits a porous structure with major elemental compositions of Oxygen (O, 50.9%), Calcium (Ca, 22.6%), Carbon (C, 20.1%), and Silicon (Si, 4%). These findings indicate that Aggregate B is predominantly composed of calcium oxide and silica.

Scanning Electron Microscopy (SEM) Coarse Aggregate C

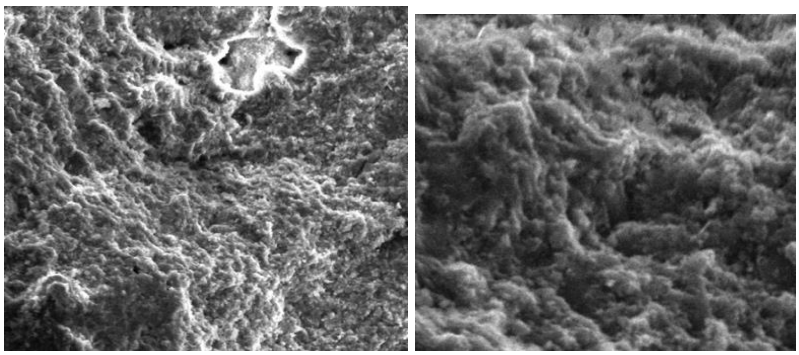

Figure 5. SEM Results of coarse aggregate sample C

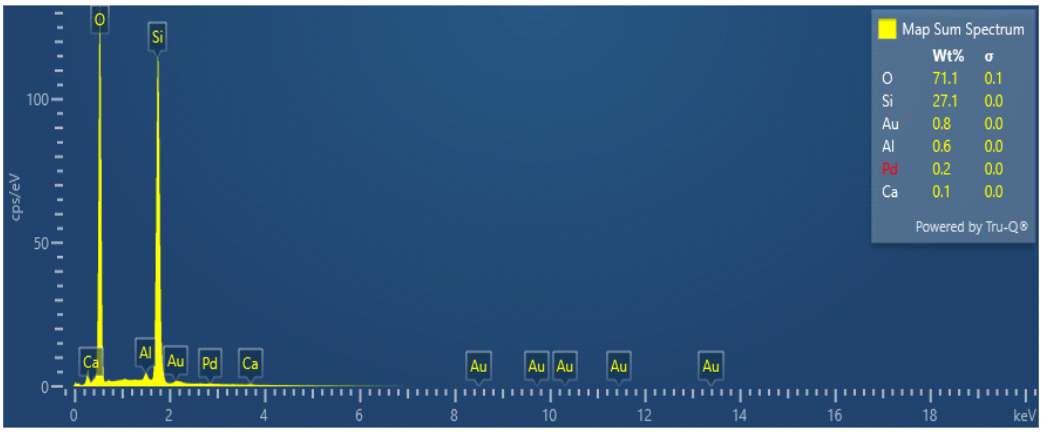

Figure 6. SEM Spektrum Results of coarse aggregate sample C

Based on the test results, Aggregate C exhibited dominant elements of Oxygen (O, 71.1%) and Silicon (Si, 27.1%). The predominance of O and Si indicates that the material is primarily composed of silica compounds (SiO_2). At higher magnifications, the sample surface appeared rough and dense, with a layered and uneven texture. The presence of micropores and small cracks distributed across the surface suggests a brittle nature and a potential susceptibility to fracture under certain mechanical stresses.

The SEM-EDS results of Aggregates A and B revealed porous morphologies with a considerable Ca content, whereas Aggregate C was dominated by Si–O elements with relatively low Ca content. According to previous findings (Luo et al., 2024), aggregates containing Ca and sufficient surface porosity can facilitate the formation of calcite precipitates and provide pore spaces for crack healing. Therefore, Aggregates A and B are considered to have greater potential as concrete admixtures compared to Aggregate C

4. Conclusion

This study has demonstrated that fakfak local aggregates, characterized using SEM-EDS posses significant Calcite content and mix of Silica and Dolomite phases which present challenges such as Calcium-Oksida reactions and variable mechanical strength. Despite these limitations, their effective use in concrete applications is feasible with appropriate treatments, such as supplementary cementitious materials and surface modifications, to enhance durability and performance. The findings highlight the potential for these aggregates to contribute to sustainable construction practices, provided that further research is conducted to optimize reinforcement strategies and asses long-term impacts.

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