CHAPTER II
LITERATURE REVIEW

2.1 Introduction

Literature review is performed to increase understanding of topics studied. The literature review can be divided into related topics and summarized.

2.2 Effect of mechanical in cement mixture of stone dust

Stone dust (SD) finds frequent application in concrete production due to its widespread availability and cost-effectiveness. Many researchers (Priyanka and Dilip, 2013; Wakchaure, Shaikh, and Gite, 2012; Mahzuz, Ahmed, and Yusuf, 2011) have been find that solid wastes as an alternative material as fine aggregate include fly ash, slag limestone, waste plastic and SD. The literature review further indicates the potential of stone dust (SD) as a substitute for conventional cement concrete materials. Prior research has extensively investigated the influence of incorporating SD on the strength properties of cement concrete, specifically when utilized as a replacement for fine aggregate.

Suman (2018) investigated the use of SD as a partial replacement for fine aggregate in concrete. The proportion of materials containing cement, fine aggregate, coarse aggregate are 1:1.54:3, with a water-cement ratio of 0.42 and a superplasticizer dosage of 0.6% by weight of cement. Figure 2.1 presents the compressive strength results at 28 days, demonstrating that all concrete mixtures containing varying replacement levels of natural sand with SD exhibited strength exceeding the reference value. These findings suggest that SD incorporation can lead to beneficial outcomes in terms of concrete strength. Similar trends observed in the test results of Singh, Srivastava, and Agarwal (2015) further support the potential of SD for achieving both environmental and strength-related benefits.

Rajput (2018) finds alternative materials to fulfill the need for fine aggregate. Employed cement, coarse aggregate, and a combination of natural sand and stone dust as fine aggregate materials are selected and water with no plasticizer. From Figure. 2.2, the results have shown that replacing natural sand with increasing amounts of SD leads to higher compressive strength in cement concrete compared to concrete made only with natural sand. This approach can also reduce waste materials generated by the mining industry.

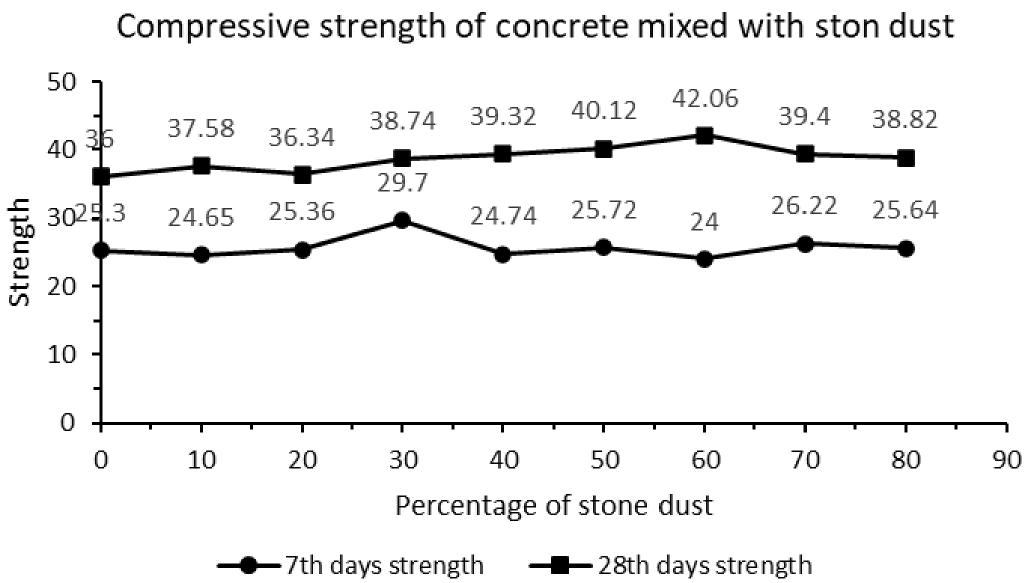

Figure 2.1 Variation of compressive strengths with gradual increase percentage of stone dust (Suman., 2018).

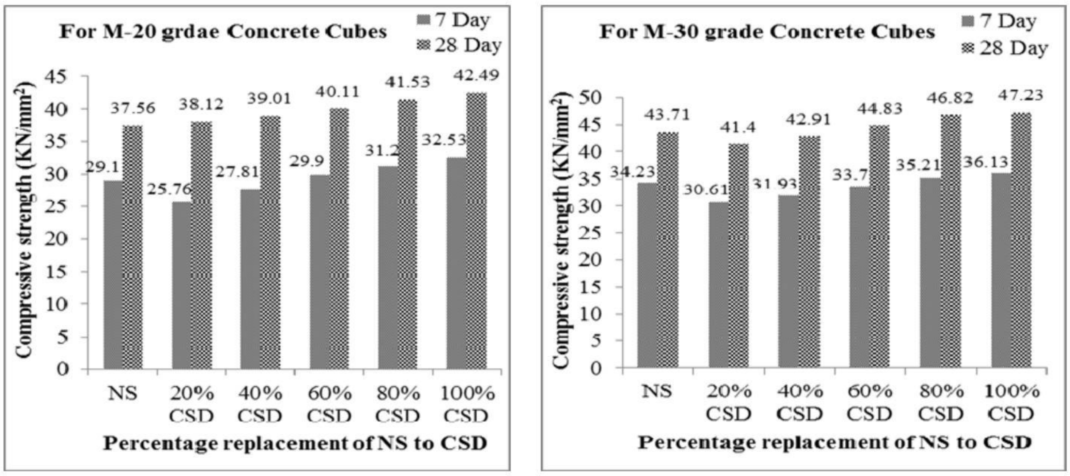

Figure 2.2 Compressive strengths of cement cube concrete with percentage replacement of NS to SD (Rajput., 2018).

Rajput and Chauhan (2014) study explore the use of stone dust as a fine aggregate in cement mortar, investigating its potential as a cost-effective alternative to river sand. The research findings indicate that stone dust can contribute to an increase in the compressive strength of cement mortars compared to those formulated with traditional river.

2.2.1 Effect of particle size

Yalley and Sam (2018) investigate the effects of fine sand content and water-to-cement ratio on concrete properties. Particle sizes range from 0.6 to 0.075 mm. They use fine sand contents of 2%, 4%, 6%, 8%, 10%, and 12% along with water-to-cement ratios of 0.55, 0.6, and 0.7. A basic 1:2:4 concrete mix is prepared. Their results show that concrete strength decreases significantly when the fine sand content exceeds 4% and the water-to-cement ratio is greater than 0.55. This might be because concrete with a higher fine sand content absorbs more water. To improve workability, it is recommended to limit fine sand content to 4% and use admixtures instead of increasing the water content.

Ghafoori, Spitek, and Najimi (2016) investigates the influence of limestone stone dust size and content on the compressive strength of self-consolidating concrete (SCC). by replacing 10, 15, and 20% of cement with limestone stone dust particles of 3 and 8 micrometers. As shown in Figure 2.3, the particle size distributions of limestone stone dust, cement, and fly ash indicate that both limestone stone dust particles are finer than those of Portland cement and fly ash. This allows them to act as fillers between cement particles, potentially improving the quality of the paste. Consequently, the compressive strength test results show an increase, likely due to the limestone stone dust filling the smaller voids between the cement particles. Thongsanitgarn, Wongkeo, Sinthupinyo, and Chaipanich (2011) also observe that increasing the amount of fine stone dust can increase concrete strength. They attribute this to two factors: (1) the very fine SD particles might act as nuclei for precipitation of Calcium Silicate Hydrate (CSH), thus increasing the degree of cement hydration, and (2) the increase in SD content and decrease in water content might reduce bleeding in the concrete mixes. For these reasons, to achieve good strength and reduce the risk of cracking, it is important to maintain a sufficient cementitious paste volume (Li and Kwan, 2015). On the other hand, Dhir, Limbachiya, McCarthy, and Chaipanich (2007) demonstrates that at equal water-to-cement (w/c) ratios, with equal cement and water contents, the strength of concrete mixes actually decreases as the limestone content increases. However, the differences between Portland limestone cement concrete containing 15% limestone and Portland cement concrete are minimal, as shown in Figure 2.4. This finding aligns with the observations of many other researchers, who have shown that the compressive strength reaches a maximum value at a certain point and then decreases as the percentage of stone dust increases (Suman, Singh, and Srivastava, 2015; Prakash and Rao, 2016; Suman, 2018; Ali and Saikrishnamacharyulu, 2021).

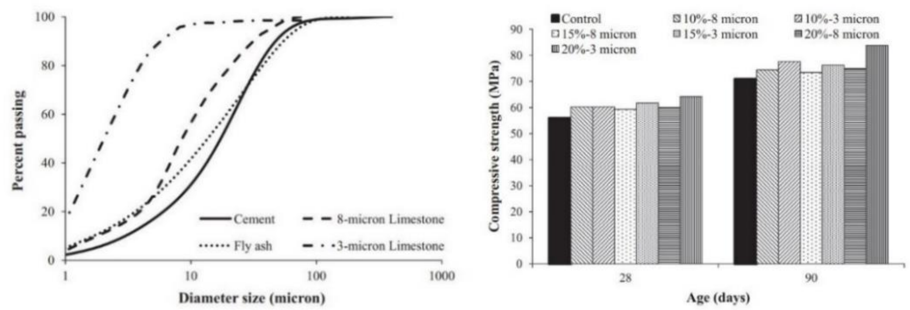

Figure 2.3 Particle size distribution of Portland cement, fly ash and limestone stone dust (left) and compressive strength of the selected SCCs (right) presented by (Ghafoori et al., 2016).

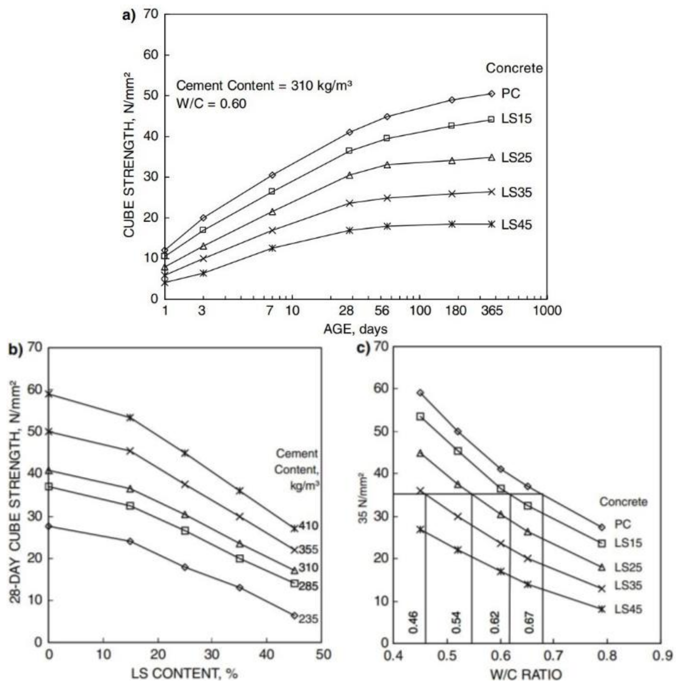

Figure 2.4 (a) Strength development and effect of (b) limestone content and (c) w/c ratio on 28-day cube strength of Portland cement and Portland limestone cement concretes (curing; 20°C water). (Dhir et al., 2007).

Neville (1995) describes how the use of a larger maximum size of aggregate affects strength in several ways. Because larger aggregates have less specific surface area and a weaker bond with the paste, failure occurs along the aggregate surfaces, resulting in reduced compressive strength of concrete. For a given concrete volume, using larger aggregates translates to a smaller volume of paste, which in turn provides more restraint to volume changes in the paste. This restraint can induce additional stresses in the paste, potentially creating microcracks before any load is applied. These microcracks can be critical factors in very high-strength concretes. Therefore, the general consensus is that using smaller sized aggregates is preferable for producing higher strength concrete.

Suwansukrot (2007) studies the effect of rock size on the compressive strength of concrete. They test concrete specimens made with Portland cement type 1 and water-reducing and accelerating additives. The compressive strength is measured at ages of 1, 3, 7, and 28 days, with 20 blocks tested at each age. Their results show that larger rocks exhibit higher compressive strength in the early stages (1 and 3 days). However, smaller rocks achieve greater compressive strength at later ages (7 and 28 days).

Haleerattanawattana (2004) studies the physical and mechanical properties of rock aggregates ranging from 3/8 inch to 1 inch in size. Finds that larger aggregates generally exhibit better physical properties compared to smaller ones. These properties include water absorption, unit weight, and the amount of void space between particles. In contrast, smaller aggregates tend to have a higher flakiness index (ratio of width to thickness) and elongation index (ratio of length to average thickness) than larger aggregates. For mechanical properties, however, the situation is reversed due to factors related to the crushing process. Smaller aggregates typically demonstrate higher strength, better compaction resistance, and greater resistance to erosion compared to larger aggregates.

2.2.2 Effect of particle shape

Neville (1995) describes the particle shape and surface texture are important external characteristics of aggregates. Roundness is a quantitative measure of a particle's relative sharpness, specifically its edges and corners. This property is primarily influenced by the inherent strength and abrasion resistance of the original rock from which the particle originates, as well as the extent of wear and tear it has undergone. When dealing with crushed aggregates, the final particle shape is determined by two key factors: the geological characteristics of the parent rock and the specific type of crusher employed, along with its reduction ratio (the degree to which the crusher diminishes particle size). Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. The shape of fine aggregate particles influences the mix properties; angular particles requiring more water for workability. Coarse aggregate particles with equip-dimensional shape are preferred. Flaky particles affect adversely the durability of concrete because they tend to be oriented in one plane. The mass of flaky particles expressed as a percentage of the mass of the sample is called the flakiness index. Even though limits are not set down, the presence of elongated particles in excess of 10 to 15% of the mass of coarse aggregate is generally considered as undesirable (Dinku, 2005).

2.3 Application of stone dust mixture

Many researchers are reported that stone dust potential can be used as sub-base material in flexible pavements and embankment material (Satyanarayana et al., 2013), fill material (Singh et al., 2015), and road construction material (Pradeep, Satyanarayana, and Raghu 2013). Their potential can be supported as follow;

Lee and Baek (2023) studies the optimal mixing ratio for backfill material used in road excavation and restoration. By utilizing the entire amount of stone sludge generated during aggregate production. They analyze factors like flowability and material separation resistance to determine the ideal mix. The stone sludge used has a 100% passing rate on a 5-mm sieve and a 47.54% passing rate on a 0.075-mm sieve. Tests show that as the water-to-stone sludge-cement ratio increases, the flowability of the mixture improves, but the strength decreases. Among the tested, a stone sludge-cement ratio of 300% to 500% provides a satisfactory balance between flowability and strength for this application. Long-term monitoring conducted over approximately 5 months revealed no ground subsidence caused by traffic loads. Additionally, the backfill material proved to be suitable for re-excavation using standard equipment. Upon re-excavation, the team checked the filling properties around pipes and found no significant filling or damage to the pipes.

Prokopski, Marchuk, and Huts (2020) studies the use of granite dust in concrete mixtures as a way to utilize industrial waste in concrete production. This approach has the potential to reduce energy consumption and improve the quality of building materials. by creating standard cube samples and testing their compressive strength at various ages. The study also considers different mix proportions for the concrete. Findings show that the addition of granite dust accelerates the kinetics of concrete hardening, resulting in a faster rate of strength increase. This phenomenon can be attributed to the partial replacement of sand with dust, which leads to a more compacted microstructure in the cement matrix. This compaction is the main reason for the observed increase in concrete strength with the addition of dust. Overall, granite dust has a positive effect on both the early strength of concrete and the strength after longer curing periods, such as 90 and 180 days.

Satyanarayana (2016) describes natural soils containing plastic fines, such as silt and clay, can deform under heavy loads, potentially leading to failures. In geotechnical applications, crusher dust from crushing plants and river sand are commonly used to evaluate the performance of mixtures made with these materials. Compaction, compressive, and seepage tests are performed to assess the engineering properties of these mixes. The experimental data indicates that a mixture containing 60-70% crusher dust and river sand produces satisfactory results. This mixture is suitable for use as sub-grade and fill materials in various geotechnical construction projects. These findings align with the test results obtained by Sridharan, Soosan, Babu, and Abraham (2005, 2006) in their studies on quarry dust.

2.4 Effect of mechanical and hydraulic properties on bentonite and aggregate mixtures

2.4.1 Compaction

Charlermyanont and Arrykul (2005) study the compaction test on bentonite-sand mixtures to determine the optimal water content and maximum dry density. The results indicated that the dry unit weight of the bentonite-sand mixture rises with increasing water content. Once the optimal water content is reached, however, the dry unit weight diminishes with further water content increments. Consistently, augmenting the amount of bentonite leads to an increase in optimal water content and a decrease in maximum dry unit weight. Subsequent addition of water beyond the optimum content precipitates a significant decrease in the dry unit weight of the compacted bentonite-sand mixtures, particularly evident at high bentonite content. These findings align with those reported by Kaya and Durukan (2004) and Cai et al. (2020).

Srikanth and Mishra (2016) study the impact of sand content of a specific size on the behavior of bentonite-sand mixture across various ratios. Two bentonites of different mineralogical composition are selected for the study. These bentonites are named Bentonite 1 and Bentonite 2. They prepared different combinations of bentonite-fine sand (FS) and bentonite-medium sand (MS) by adjusting the sand content from 50 to 90 % by the dry weight of the mixture. Bentonite-FS and bentonite-MS mixtures demonstrated distinct optimal water content and maximum dry density values, suggesting a potential influence of sand particle size on compaction characteristics. Mixtures containing MS exhibited comparatively higher maximum dry density and lower optimal water content values for both type of bentonites, likely due to the effective packing of bentonite particles within the void spaces formed among the sand particles.

The behavior of bentonite-sand mixtures depends on the of bentonite content. With a low bentonite content, the mixture retains the characteristics of granular soil. However, as the bentonite proportion increases, there's a gradual transition of the mechanical properties typical of plastic clay. This interaction between bentonite and sand is using Scanning Electron Microscopy (SEM), as shown in Figure 2.5, it reveals bentonite particles adhere to the surface of sand grains, forming "bridges" that connect the larger particles. (Proia, Croce, and Modoni, 2016).

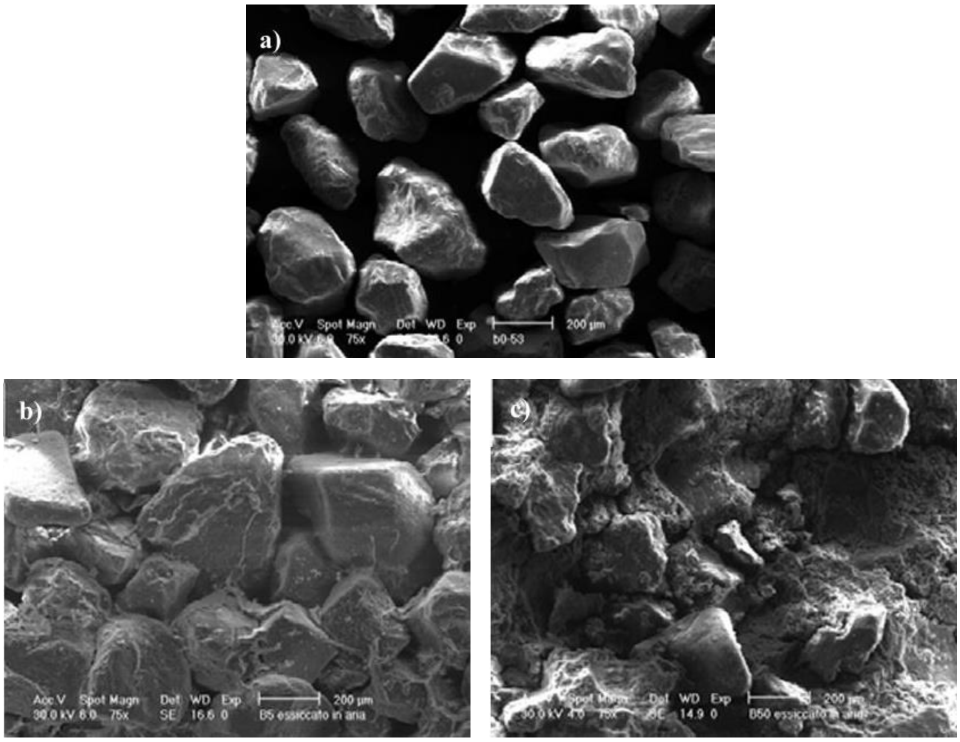

Figure 2.5 SEM of dried samples at magnification factors of 75x; a) with sand 100%, b) with bentonite 5%, and c) with bentonite 50% (Proia et al., 2016).

2.4.2 Direct shear test

Yanrong (2013) investigates the shape and size variation of particles affect the shear behavior of composite soils containing a broad spectrum of particle sizes. Two sets of comparable samples are created: (1) a combination of fine particles (clay and silt) with a perfectly shaped coarse fraction (glass sand and beads), and (2) a combination of fine particles with a naturally occurring coarse fraction (river sand and crushed granite gravels). The results showed that an increase in the proportion of coarse particles led to a higher constant volume shear strength. Additionally, as the elongation of the coarse particles increased, or their convexity decreased, the constant volume friction angle also increased. The overall roughness of the shear surface, when the volume remains constant, has a negative correlation with the smoothness (convexity) of the particles and a positive correlation with the area of the shear surface occupied by particles of specific shapes. To quantify the particle shape, two parameters, convexity and elongation, are derived from 2D images of the soil particles. As shown in Figure 2.6.

The relationship between shear strength and particle size is then analyzed by Bagherzadeh-Khalkhali and Mirghasemi (2009). The results indicate that samples with larger maximum particle sizes exhibit greater shear strengths. This is because the value of the shear parameter is dependent on the size of the grains. while the friction angle increases as the grain size increases, as confirmed by research from Soltani-Jigheh and Jafari (2012), and Kim and Ha (2014).

Vangla and Latha (2015) investigate the influence of particle size distribution on the shear behavior of sand. Their symmetric direct shear tests revealed that particle size itself does not affect the peak friction angle when the tests are conducted at the same void ratio. However, the ultimate friction angles are impacted by particle size, with larger particles exhibiting higher ultimate friction angles. Figure 2.7 shows the shear stress and displacment response of the sands is influenced by their angularity. Increased angularity resulted in higher peak shear strength due to an enhancement in interlocking forces between the particles. It's important to note that the sands had relatively similar angularity and roundness properties. This suggests that the morphological effects are negligible, and the observed variations in shear behavior are primarily due to differences in particle size. This aligns with the findings of Holtz and Kovacs (1981), who reported that particle size has no effect on the peak friction angle if the void ratio remains constant.

Circularity	1	0.47	0.89	0.52	0.47	0.21
Convexity	1	1	1	1	0.70	0.73
Elongation	0	0.82	0	0.79	0.24	0.83

Figure 2.6 Illustration of particle shape parameters (Yanrong, 2013).

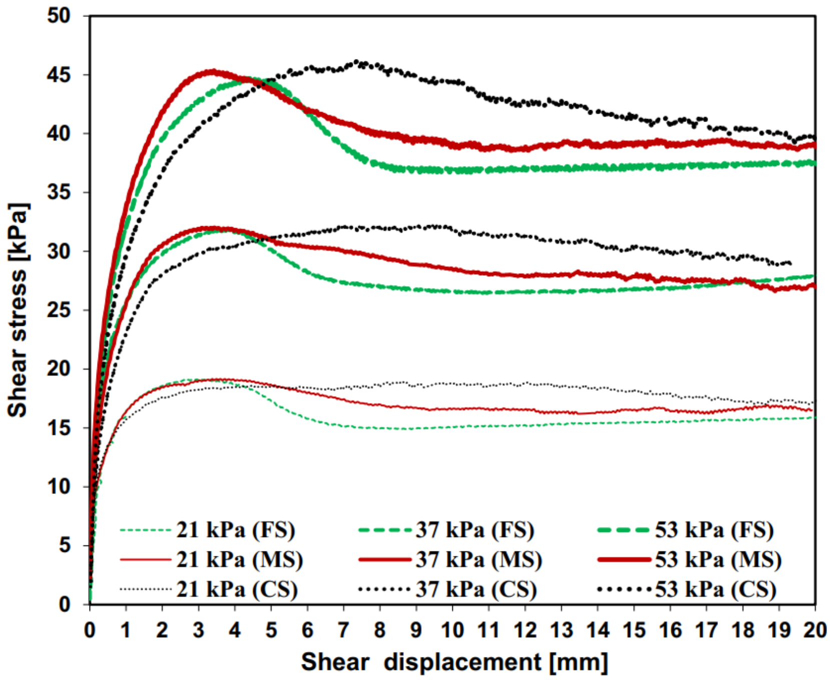

Figure 2.7 Shear stress versus shear displacement response of different sands (Vangla and Latha, 2015).

2.4.3 Consolidation test

Duong and Hao (2020) study the consolidation characteristics of artificially structured bentonite-kaolin mixtures with different pore fluids. Oedometer tests are conducted on bentonite-kaolin mixtures containing 10%, 20%, and 30% bentonite content. Distilled water is used as pore fluids. Samples are consolidated to create an "artificial structure". Bentonite significantly impacts the consolidation behavior of mixtures. Compression index, swelling index, and coefficient of volume change increased with increasing bentonite content.

Pastor, Tomás, Cano, Riquelme, and Gutiérrez. (2019) study the improvement of clayey soils by using limestone dust addition. All the samples are compacted at 0, 5, 10, 15, 20, and 25% of limestone dust. Tests are one-dimensional consolidation tests conducted under the loading sequence of 5 up to 800 kPa and unloading sequence of 400 up to 20 kPa. From the test result, increase in the stiffness of the clayey soil by 27% when 25% limestone dust is added. The compression index, which is a direct indication of the tendency of a clayey soil to settle when it is loaded, decreases as the amount of additive increases. A similar trend is observed for swelling index with a maximum reduction of 31% when 25% of limestone dust is added. This lower compressibility of the mixed clayey soil is attributed to the fine aggregates of the limestone stone dust filling the voids of the clayey soil. This agrees reasonably well with the test results obtained by Mishra et al. (2010) who study the effect of the physical, chemical and mineralogical properties on the 15 different bentonite-soil mixtures.

2.4.4 Swelling test

Pastor et al. (2019) describe the effect of adding limestone dust on the free swelling of the soil. The result found that the swelling index reduced from 5.7% to 3.38% when only 5% of limestone dust is added. This constitutes a reduction of 42% in the swelling index of the mixed soil. Reductions of 58%, 61%, and 56% are observed when the limestone stone dust addition is 10, 15, and 20%, respectively. The results are consistent with previous research (Saygili, 2015; Sabat and Nanda, 2011), show a decrease in the swelling index with increasing marble dust up to the maximum amount. Ogila (2016) report that a decrease between 30 to 45% of the heave percentage of swelling index when 20% of limestone dust is added to clayey soils, similar to results obtained by Sabat and Muni (2015). The increase of the swelling index while 25% limestone stone dust addition is due to the significant increase in matric suction caused by the reduction in the initial water content of the samples. This is because the stone dust is added dry to the wet soil.

Srikanth and Mishra (2016) indicate that compacted bentonite-soil mixtures are utilized in waste disposal and nuclear waste sites. The particle size of sand in bentonite mixtures affects their behavior, with fine sand mixtures displaying higher shrinkage limits. Mixtures with medium sand have higher density and lower water content. Sand content influences engineering properties, with fine sand mixtures showing higher liquid limits and swelling pressure. Additionally, fine sand mixtures exhibit lower hydraulic conductivity due to effective void filling. The result indicate that bentonite content below 20% is insufficient for filling void spaces. The results similarly with of Bilal and Ahmad (2020) who study the soil swell potential on bentonite-stone dust mixtures. When used the stone dust in range of 10, 20, 30, 40 and 50% and concluded that only 30% is enough to improve soil properties. The reason why stone dust improves soil properties is that it possesses a pozzolanic nature and contains coarse particles that improve compaction characteristics and reduces the plasticity. Moreover, it has good interlocking strength with soil because of its angular shape.

2.5 Permeability properties of stone dust

Akbulut and Cabalar (2014) study the effects of physical properties of sand (e.g., size and shape) on the hydraulic conductivity. Five materials with different sizes and particle shapes are used in this study. By permeability testing apparatus is employed for the experiments. The experimental results show that relatively rounded sand grains have decrease hydraulic conductivity values than the angular sand grains. This is because increase particle rotation allows for a more open fabric in angular sand grain samples compared to rounded ones. Consequently, more angular sand exhibit higher hydraulic conductivity values. According to by Cedergren (1989) and Sperry and Peirce (1995) show that particle shape affects both permeability and liquefaction potential. Horak, Sebaaly, Maina, and Varma (2017) shows this concept by zooming in on the voids of the three levels consecutively filled with smaller and smaller aggregate grading groupings. This allows for clear visualization of the main structural elements within each consecutively smaller of the grain matrix, without the influence of finer aggregates filling the voids. The latter mainly provide stability to this grain matrix (Figure 2.8).

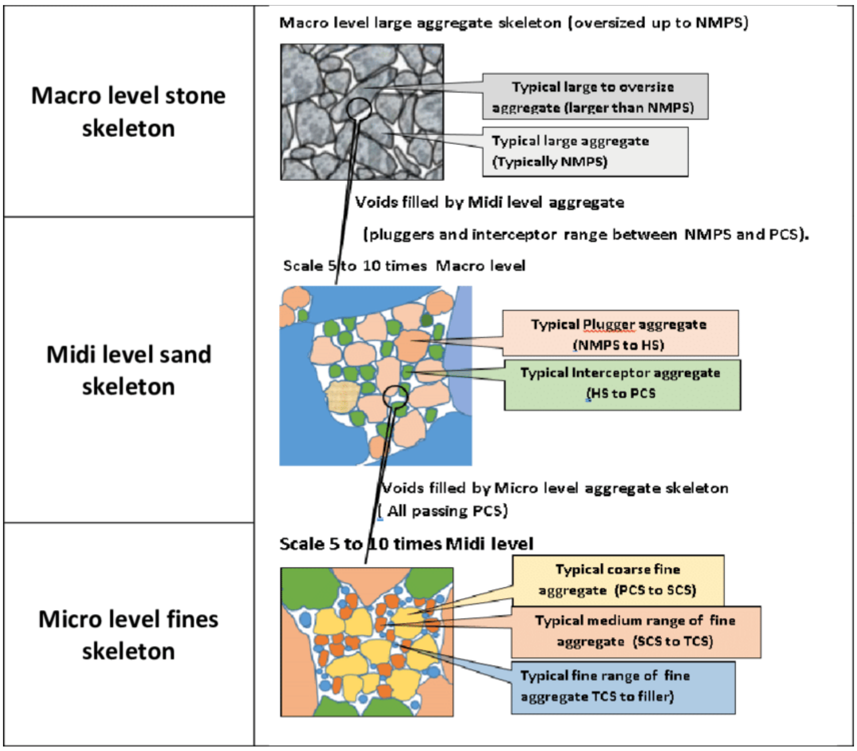

Figure 2.8 Three level grain matrix infill illustration (Horak et al., 2017).

2.6 Weight ratio of bentonite-stone dust mixture

Jain, Jha, and Akhtar (2022) describes marble dust (MD) as a viable alternative to sand (S) when mixed with bentonite (B). Microstructural images with 20% bentonite content show the filling and coating of bentonite particles within the inter-particle voids and on the surface of the sand and marble dust particles. This process transforms the coarse-grained matrix into a coarse-grained cohesive matrix (Fig. 2.9 c and f). Furthermore, a 40% bentonite content induces the adherence of bentonite particles on the surface of sand and marble dust particles, thereby forming a compacted matrix (Fig. 2.9 b and e). However, with a higher bentonite content of 60%, the sand and marble dust particles become noticeably immersed within the bentonite matrix. Based on this preliminary assessment, optimal results are achieved when sand or marble dust constitutes less than 40% of the mixture, indicating a requirement for a higher bentonite content for developing landfill liners. This aligns report by Pusch (1998) that a 30% bentonite content is effective for backfill applications. The recommendations by Sobti and Singh (2017) for optimal barrier material compositions are as follows: sand-bentonite with 10% bentonite content, coal ash-bentonite with 10% bentonite content, and silt-bentonite with 5-10% bentonite content. It is important to note that a 5% bentonite content for sand and coal ash mixtures may not be sufficient, as indicated by the higher hydraulic conductivity (k) value observed in these cases. On the other hand, a stone dust content of 20-30% is sufficient to improve soil properties. The reason stone dust enhances soil properties is that it possesses pozzolanic characteristics and contains coarse particles, which improve compaction characteristics and reduce plasticity. Moreover, it has good interlocking strength with the soil due to its angular shape.

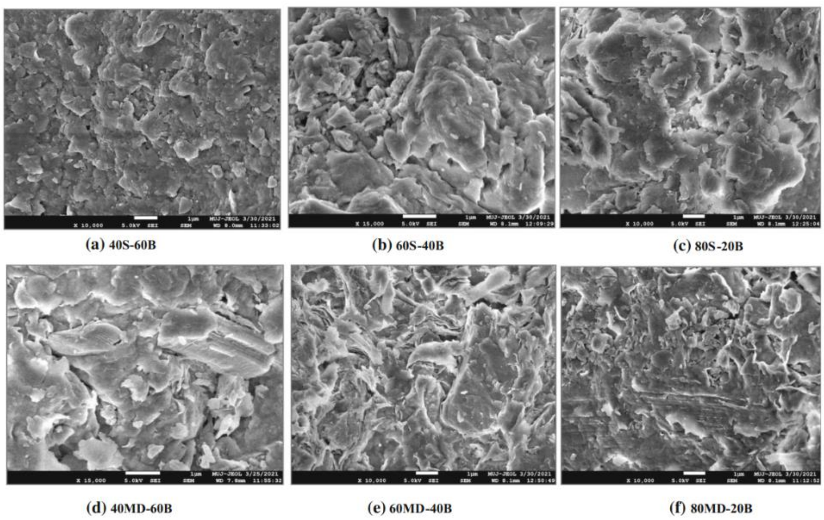

Figure 2.9 Microstructural examination of S–B and MD–B mixes Jain et al. (2022).