



REVIEW ARTICLE

SUITABILITY OF LOCALLY SOURCED SOILS AS FINE AGGREGATES IN CONCRETE PRODUCTION - A REVIEW

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ABSTRACT

The increasing demand for concrete has intensified the exploitation of natural river sand used as fine aggregate, resulting in material scarcity, rising construction costs and environmental degradation from excessive sand mining. This has encouraged the search for sustainable alternative materials, including locally sourced soils, for partial replacement of river sand in concrete production. This study presented a structured review of experimental investigations on the use of lateritic, sandy, silty and clayey soils as fine aggregates in concrete. A total of 10 experimentally validated studies published majorly between 2015 and 2024 were systematically reviewed. The review evaluated the effects of these soils on workability, compressive strength, durability and cementitious interactions within the concrete matrix. Findings indicated that well-graded sandy soils and lateritic soils with low clay content can replace approximately 10–30% of river sand without significant reduction in compressive strength. Quantitative analysis showed that optimum replacement levels generally ranged between 15–25%, producing compressive strengths of approximately 24–30 MPa suitable for normal structural concrete applications. The review further revealed that soils containing appreciable silica (SiO_2) and alumina (Al_2O_3) may contribute to secondary pozzolanic reactions and improved matrix densification. However, excessive clay content (>8–10%) increased water demand, reduced workability, weakened cement–aggregate bonding and negatively affected durability performance. The use of locally sourced soils may reduce dependence on river sand and lower transportation costs in developing regions. Although preliminary durability performance at moderate replacement levels was satisfactory, further investigations involving permeability, sulphate resistance, shrinkage, carbonation and long-term durability are required before widespread structural application. The study highlighted the potential of locally sourced soils as sustainable supplementary fine aggregate materials when proper characterization, grading and mix proportioning are adopted.

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1.0 Introduction

Concrete remains the most widely utilized construction material in civil and structural engineering because of its high compressive strength, durability, versatility and relatively low production cost. The performance of concrete is strongly influenced by the properties and proportions of its constituent materials, particularly cement, water, coarse aggregates and fine aggregates (Neville, 2015; Mehta and Monteiro, 2017). Fine aggregates play a critical role in improving particle packing, reducing voids between coarse aggregates and enhancing the workability, density and mechanical performance of concrete mixtures. Natural river sand has traditionally served as the principal source of fine aggregate due to its suitable grading characteristics, availability and relatively low impurity content (Shetty, 2019; ASTM, 2018). However, rapid urbanization, population growth and increasing infrastructure development have significantly increased global demand for construction sand. Recent studies indicated that approximately 40–50 billion tonnes of sand are consumed

annually worldwide, making sand one of the most exploited natural resources after water (UNEP, 2019). Excessive sand mining had contributed to severe environmental problems including riverbank erosion, ecosystem degradation, lowering of groundwater tables and destruction resulted in scarcity of quality river sand and increased construction costs (UNEP, 2019).

In response to these environmental and economic concerns, researchers have increasingly investigated alternative materials capable of partially or fully replacing natural river sand in concrete production. Previous studies had examined the use of quarry dust, manufactured sand, recycled fine aggregates, industrial by products and agricultural wastes as sustainable alternatives to conventional fine aggregates (Thomas *et al.*, 2013; Ukpata *et al.*, 2024). Among these alternatives, locally sourced soils such as lateritic, sandy, silty and clayey soils have attracted growing attention, particularly in tropical regions where such materials occur abundantly and are easily accessible. Experimental investigations have shown that properly graded lateritic and sandy soils can partially replace river sand at moderate replacement levels without significant reduction in compressive strength and workability (Adetayo *et al.*, 2019; Ukpata *et al.*, 2024). Olanitori *et al.*, (2006) similarly reported acceptable strength with moderate replacement but noted reduced workability at higher percentage. In addition, the utilization of locally available soils may reduce dependence on commercially mined sand, minimize transportation costs and promote sustainable utilization of indigenous construction materials in developing regions. Despite the increasing number of studies on soil based fine aggregate replacement in concrete, existing findings remained fragmented across different soil types, geographical regions and experimental conditions (Ajagbe *et al.*, 2018). Many previous studies had focused primarily on compressive strength performance, with comparatively limited attention given to durability characteristics, mineralogical interactions and long-term engineering behaviour of soil modified concrete. Furthermore, several existing reviews broadly discussed alternative fine aggregates without providing a focused synthesis of the engineering performance of locally sourced soils under varying replacement levels and soil characteristics (Das and Sobhan, 2018; Mehta and Monteiro, 2017).

Variations in particle size distribution, plasticity, clay content and mineral composition significantly influence the behaviour of soil modified concrete, yet a comprehensive comparative evaluation of these parameters remains limited in the literature. Excessive clay or silt fractions may increase water demand, reduce workability and weaken cement–aggregate bonding, while soils containing reactive silica and alumina may contribute positively to matrix densification through secondary pozzolanic reactions (Das and Sobhan, 2018; Adetayo *et al.*, 2019). Therefore, this study presented a focused review of existing experimental investigations on the use of locally sourced soils as alternative fine aggregates in concrete production. The review critically evaluated the influence of soil characteristics, replacement percentages and material composition on the workability, compressive strength and durability performance of concrete (Ukpata *et al.*, 2024). In addition, the study identified optimum replacement ranges, summarized prevailing engineering trends and highlighted existing research gaps requiring further investigation. The review is intended to provide a clearer understanding of the suitability of locally sourced soils for sustainable concrete production and to support future development of standardized guidelines for their practical application in construction (UNEP, 2019; ASTM, 2018).

2. Role and Engineering Requirements of Fine Aggregates in Concrete

Fine aggregates constitute an essential component of concrete and significantly influence the fresh and hardened properties of concrete mixtures, including workability, density, strength development, permeability and long-term durability (Neville, 2015; Mehta and Monteiro, 2017). In conventional concrete systems, fine aggregates occupy the voids between coarse aggregates and contribute to particle packing efficiency, thereby reducing porosity and improving the compactness of the hardened matrix (Shetty, 2019). Well graded fine aggregates also reduce the quantity of cement paste required to fill interparticle spaces, improving both the economic efficiency and dimensional stability of concrete. The engineering performance of concrete therefore depends strongly on the physical, chemical and mineralogical characteristics of the fine aggregate used. In recent years, increasing attention has been directed toward the use of locally sourced soils as partial replacements for natural river sand due to growing environmental concerns associated with excessive sand mining and the rising cost of conventional fine aggregates. However, the suitability of these soils depends on their grading characteristics, clay content, mineral composition, water absorption behavior and interaction with cement hydration products. Unlike conventional river sand, locally sourced soils exhibit considerable variability in particle size distribution, plasticity and mineralogical composition, resulting in significant differences in concrete performance across different soil types and replacement levels.

2.1 Standard Requirements for Fine Aggregates

To ensure satisfactory concrete performance, fine aggregates must satisfy established engineering requirements relating to grading, cleanliness, durability and chemical stability. International standards such as ASTM C33, BS 882 and IS 383 specify allowable limits for particle size distribution, deleterious substances, clay content and organic impurities in aggregates used for concrete production (ASTM, 2018; BIS, 2016). These standards are particularly important when evaluating locally sourced soils because excessive fines and clay minerals may adversely affect concrete properties. Studies reviewed in this research consistently showed that soils containing high clay or silt fractions exhibited increased water demand and reduced workability compared with conventional river sand mixtures (Das and Sobhan, 2018; Shetty, 2019).

Highly plastic soils were also associated with lower compressive strength and increased permeability due to weaker interfacial bonding between soil particles and hydrated cement paste. In contrast, well graded sandy soils with low plasticity generally demonstrated engineering behavior comparable to conventional fine aggregates, particularly at moderate replacement levels below 25% (Adetayo *et al.*, 2019; Ukpata *et al.*, 2024). The reviewed studies further revealed that compliance with aggregate grading standards significantly improved concrete performance by reducing voids and enhancing particle packing. Properly graded soils produced denser concrete matrices with lower water absorption and improved resistance to cracking compared with poorly graded or highly clayey soils (Mehta and Monteiro, 2017; Neville, 2015).

2.2 Influence of Aggregate Properties on Concrete Performance

The engineering behavior of concrete containing locally sourced soils depended strongly on aggregate characteristics such as particle size distribution, plasticity, specific gravity, water absorption capacity and mineralogical composition. Comparative analysis of reviewed studies indicated that these properties collectively influenced workability, density, compressive strength, durability and failure mechanisms in soil modified concrete (Mehta and Monteiro, 2017; Das and Sobhan, 2018).

2.2.1 Particle size distribution and density characteristics

Particle size distribution is one of the most influential parameters controlling the performance of soil-modified concrete. Well graded soils improved packing density within the concrete matrix, reduce internal voids and enhance compressive strength through improved aggregate interlock (Neville, 2015; Shetty, 2019). Several reviewed studies reported that sandy soils with continuous grading produced denser concrete and lower porosity compared with lateritic or clayey soils containing excessive fines. Adeyemi and Olowu (2017) reported that properly graded sandy soil used as partial fine aggregate replacement produced compressive strength values comparable to conventional river sand concrete, although additional grading adjustment was necessary to improve particle distribution and workability characteristics. Density variations among different soil types were strongly linked to fines content and specific gravity (Mehta and Monteiro, 2017; Adetayo *et al.*, 2019). Concrete containing well graded sandy soils generally exhibited densities comparable to conventional concrete, while mixtures containing excessive clay fractions showed reduced density due to higher water demand and entrapped voids. Lower density values were commonly associated with increased porosity and reduced mechanical performance at replacement levels exceeding 25–30% (Das and Sobhan, 2018; Ukpata *et al.*, 2024).

2.2.2 Plasticity, water absorption and workability trends

Plasticity significantly affected the fresh properties of soil modified concrete. Highly plastic soils contain large proportions of clay minerals capable of absorbing substantial quantities of water, thereby reducing the free water available for lubrication within the concrete mix (Das and Sobhan, 2018; Shetty, 2019). Comparative findings from reviewed studies consistently showed that slump values decreased with increasing soil replacement percentage, particularly in concrete containing silty or clayey soils. Olanitori and Olotuah (2006) similarly observed that moderate replacement of river sand with lateritic soil produced acceptable structural strength; however, workability decreased progressively with increasing laterite content due to higher fines concentration and water demand. Water absorption trends also varied considerably across soil types, with lateritic and clayey soils generally exhibiting higher water absorption capacities because of their finer particles and increased surface area (Mehta and Monteiro, 2017; Ajagbe *et al.*, 2018). Increased water absorption resulted in higher water demand, reduced workability and weaker cement–aggregate bonding. In contrast, well graded sandy soils demonstrated relatively stable water absorption characteristics and maintained acceptable workability at moderate replacement levels (Adetayo *et al.*, 2019; Ukpata *et al.*, 2024). At replacement levels

above 25–30%, most studies reported significant reductions in slump, increased difficulty in compaction and higher susceptibility to segregation and shrinkage cracking. These findings indicated that controlling fines content and plasticity was critical for maintaining satisfactory fresh concrete behavior (Neville, 2015; Das and Sobhan, 2018).

2.2.3 Mineralogical composition and pozzolanic interactions

The mineralogical composition of locally sourced soils strongly influenced the hydration mechanisms and microstructural development of soil-modified concrete. X-ray fluorescence (XRF) analyses reported in several studies identified significant quantities of silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) in lateritic soils and geopolymer stabilized soil systems used in construction applications (Tang *et al.*, 2023; Nkwaju *et al.*, 2023). These oxides may contribute to secondary pozzolanic reactions through interaction with calcium hydroxide released during cement hydration. Studies involving SEM and XRD analyses demonstrated that soils containing reactive silica and alumina may promote additional calcium silicate hydrate (C-S-H) formation, resulting in improved matrix densification and enhanced interfacial bonding between aggregate particles and cement paste (Tang *et al.*, 2023; Mehta and Monteiro, 2017). Moderate replacement levels therefore frequently produced satisfactory compressive strengths comparable to conventional concrete. However, soils containing excessive clay minerals such as montmorillonite and kaolinite were associated with weaker interfacial transition zones and increased microcracking due to shrinkage and moisture sensitivity (Das and Sobhan, 2018; Shetty, 2019). These mechanisms contributed to reduced durability and lower long-term strength performance. Although several studies discussed pozzolanic interactions and matrix densification, only limited microstructural evidence was presented. Few studies incorporated scanning electron microscopy (SEM), X-ray diffraction (XRD), mercury intrusion porosimetry (MIP), or Fourier transform infrared spectroscopy (FTIR) analyses to validate the formation of secondary hydration products and evaluate pore structure refinement (Tang *et al.*, 2023; Nkwaju *et al.*, 2023; Chen *et al.*, 2024). Consequently, the microstructural mechanisms governing soil modified concrete remained insufficiently investigated and require further experimental verification.

2.3 Durability Characteristics of Soil Modified Concrete

Durability performance remained one of the most critical concerns regarding the use of locally sourced soils as fine aggregate replacements in structural concrete applications. Comparative analysis of reviewed studies indicated that durability behavior depended primarily on clay content, permeability characteristics, pore structure, and water absorption capacity of the soil used (Mehta and Monteiro, 2017; Neville, 2015). Concrete containing properly graded sandy or low plasticity lateritic soils generally demonstrated satisfactory preliminary durability performance at moderate replacement levels. Lower permeability and improved particle packing were associated with denser concrete matrices and reduced water ingress, while increasing clay content consistently resulted in higher porosity, increased water absorption, and reduced resistance to environmental deterioration (Tang *et al.*, 2023; Nkwaju *et al.*, 2023). Several durability related mechanisms were identified in the reviewed studies, including increased permeability due to excessive fines and weak particle bonding, higher susceptibility to shrinkage cracking in clay-rich mixtures, and reduced resistance to sulphate attack because of increased pore connectivity (Das and Sobhan, 2018; Shetty, 2019). Additional concerns included potential acceleration of carbonation depth in highly porous concrete matrices and increased risk of chloride penetration in poorly compacted mixtures.

Despite these observations, durability evaluation in many studies remained limited primarily to water absorption and compressive strength assessment (Ajagbe *et al.*, 2018; Thomas *et al.*, 2013). Important long-term durability parameters such as chloride ion penetration, freeze–thaw resistance, alkali–silica reactivity, sulphate attack mechanisms, and carbonation resistance were rarely investigated comprehensively. Furthermore, very few studies evaluated failure mechanisms at the microstructural level. Available evidence suggested that concrete containing excessive clay fractions exhibited microcrack propagation within the interfacial transition zone due to weak bonding and shrinkage effects (Mehta and Monteiro, 2017; Das and Sobhan, 2018). However, systematic investigations combining scanning electron microscopy (SEM), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and pore structure analysis to fully explain the relationship between microstructural development and durability performance in stabilized soils remained limited, indicating the need for further long-term microstructural and durability studies (Tang *et al.*, 2023; Chen *et al.*, 2024; Nkwaju *et al.*, 2023).

2.4 Comparative Assessment of Different Soil Types

2.4.1 Lateritic soils

Lateritic soils remained the most extensively studied locally sourced soils for concrete applications due to their abundance in tropical regions such as West Africa (Amu *et al.*, 2018a). Comparative findings indicated that lateritic soils containing low clay fractions can successfully replace approximately 10–30% of river sand while maintaining acceptable compressive strength and workability characteristics (Amu *et al.*, 2018b; Ukpata *et al.*, 2024). Nwankwo and Okafor (2021) further observed that compressive strength performance declined significantly when lateritic soil replacement exceeded the optimum threshold because of increased clay content and reduced bonding efficiency. Moderate replacement levels improved cohesiveness and particle packing; however, excessive replacement increased water demand and reduced durability performance due to higher fines content.

2.4.2 Silty and clayey soils

Silty and clayey soils generally exhibited poorer engineering performance compared with sandy or low plasticity lateritic soils (Das and Sobhan, 2018). High plasticity, excessive water absorption and weak cement–aggregate bonding resulted in lower compressive strength, increased shrinkage and reduced durability resistance. These soils were also associated with greater susceptibility to microcracking and permeability related deterioration.

2.4.3 Sandy soils

Well graded sandy soils demonstrated the most favorable overall performance among the reviewed soil categories (Shetty, 2019). Their low plasticity and grading characteristics produced concrete with relatively stable density, lower water absorption and satisfactory compressive strength comparable to conventional concrete. Durability behavior was also generally superior because of improved particle packing and reduced pore connectivity.

Table I: Comparative Engineering Performance of Soil Types Used as Fine Aggregate Replacement

Soil Type	Workability	Water Absorption	Density Performance	Durability Behaviour	Major Limitation
Lateritic Soil	Moderate reduction	Moderate increase	Comparable at moderate replacement	Acceptable below 25% replacement	Increased fines at high replacement
Silty/Clayey Soil	Significant reduction	High absorption	Reduced density	Poor durability resistance	High plasticity and shrinkage
Sandy Soil	Relatively stable	Low to moderate	Comparable to conventional concrete Low density	Improved durability performance	Requires proper grading
Highly Clayey Soil	Poor workability	Very high absorption		High permeability and cracking	Weak interfacial bonding

The reviewed studies collectively demonstrated that the engineering performance of soil modified concrete depended strongly on soil classification, grading characteristics, mineralogical composition and replacement percentage. Among the reviewed soil categories, well graded sandy soils and low plasticity lateritic soils exhibited the most promising performance for sustainable concrete production. However, comprehensive long term durability investigations and microstructural analyses remained necessary before widespread structural implementation can be recommended.

3. Method

This study adopted a structured systematic literature review approach to evaluate the suitability of locally sourced soils as alternative fine aggregates in concrete production. The review methodology was designed to ensure transparency, reproducibility and objective assessment of previous experimental studies related to soil based fine aggregate replacement in concrete.

3.1 Literature Search Strategy

Relevant publications were obtained from major scientific databases including Google Scholar, ResearchGate, Scopus indexed journals and institutional repositories. The search was limited to studies published between 2015 and 2024 to ensure the inclusion of recent and technically relevant research findings. The literature search employed combinations of keywords such as “lateritic soil concrete”, “soil as fine aggregate”, “river sand replacement”, “alternative fine aggregates”, “soil-based aggregates in concrete”, “laterized concrete”, “sandy soil concrete,” and “locally sourced aggregates”. Boolean operators such as AND and OR were used to refine the search process. The initial search yielded 28 relevant publications.

3.2 Inclusion and Exclusion Criteria

Studies were selected based on inclusion criteria such as peer reviewed journal articles and conference proceedings, experimental investigations involving locally sourced soils as partial or full replacement for fine aggregates in concrete, studies reporting engineering properties such as compressive strength, workability, density, water absorption, or durability and studies providing quantitative laboratory results. The exclusion criteria included studies lacking experimental validation, duplicate publications, studies focused solely on stabilized earth blocks without concrete applications, publications without sufficient engineering data and studies unrelated to fine aggregate replacement.

3.3 Study Selection and Quantitative Synthesis

The initial database search identified 28 relevant publications related to soil-based aggregates in concrete production. Out of the initial 28 publications identified, 6 studies were excluded due to duplication across databases, while 5 studies were removed because they focused primarily on stabilized earth blocks, road stabilization or geotechnical soil improvement rather than concrete applications. An additional 4 studies were excluded because they lacked sufficient experimental data or quantitative engineering results. Three publications were also removed because of incomplete methodology descriptions, absence of replacement percentage information or lack of compressive strength and durability evaluation. Following the screening and eligibility assessment process, 10 studies that were published majorly between 2015 and 2024 were systematically reviewed and selected for detailed qualitative and quantitative synthesis. These studies were considered sufficiently relevant because they contained experimentally validated data relating to the use of locally sourced soils as partial or full replacements for fine aggregates in concrete production. To improve the analytical rigor of the review, quantitative data from the selected studies were synthesized based on replacement percentage, compressive strength, workability behaviour and observed durability performance. Average compressive strength values and optimal replacement ranges were comparatively evaluated to identify common engineering trends across the reviewed studies.

3.4 Data Organization and Analysis

A comparative statistical evaluation was also conducted using the compressive strength data reported in the reviewed studies. The analysis showed that the average optimum replacement level for locally sourced soils ranged between 15–25%, while the corresponding average compressive strength ranged between approximately 25–29 MPa. The reviewed studies consistently demonstrated that replacement levels above 30% resulted in significant reductions in workability and compressive strength due to increased fines and clay content.

Table 2: Quantitative summary of reviewed studies

Parameter	Range Observed	Average Value
Replacement Percentage	0–30	20
Optimum Replacement (%)	15–25	20
Compressive Strength (MPa)	24–31	27
Recommended Clay Content (%)	<10	8

The findings of Adeyemi and Olowu (2017) further demonstrated that sandy soils with suitable grading characteristics may provide engineering performance similar to conventional river sand, particularly at moderate replacement levels.

Table 3: Comparative summary of experimental studies on the use of locally sourced soils as fine aggregate replacement in concrete

Author(s) and Year	Study Focus	Methodology	Key Findings	Limitations
Olutoge et al. (2013)	The ultimate strength behaviour of laterised concrete beam	Experimental mix design and compressive strength testing	Comparable strength at moderate laterite replacement	Strength reduced at higher laterite content
Adetayo et al. (2019)	Cement stabilized lateritic soil in concrete	Mix design and compressive strength analysis	Acceptable structural strength achieved	Limited durability evaluation
Ukpata et al. (2024)	Performance of laterized concrete	Experimental compressive strength testing	Adequate structural strength maintained up to 30%	Workability reduced at higher replacement
Adeyemi and Olowu (2017)	Sandy soil as fine aggregate	Laboratory mix design and testing	Sandy soil performed similarly to river sand	Soil grading required improvement
Olanitori and Olotuah (2006)	Strength characteristics of laterized concrete	Experimental replacement of river sand with laterite in concrete	Acceptable structural strength at moderate replacement levels	Reduced workability with increasing laterite content
Adepegba et al. (2016)	Alternative fine aggregates	Experimental compressive strength testing	Proper grading produced comparable strength	Limited durability data
Ambrose et al. (2018)	Lateritic soil in concrete production	Workability and compressive strength tests	Laterite suitable for partial sand replacement	Workability decreased
Ajagbe et al. (2018)	Structural behaviour of laterized concrete	Laboratory compressive strength analysis	Good structural performance at moderate replacement	Increased water demand
Oladimeji et al. (2022)	Sandy soil in concrete mixes	Comparative experimental study	Comparable strength with conventional sand	Soil variability
Nwankwo and Okafor (2021)	Lateritic soil replacement	Laboratory mix design and strength testing	Optimal strength achieved below 30%	Strength declined above threshold

Table 4: Comparative analysis of replacement levels and compressive strength performance of soil modified concrete

Authors Details	Replacement (%)	Range	Optimal Replacement (%)	Compressive Strength Achieved (MPa)
Olutoge et al. (2016)	0–30		20	25–28
Adetayo et al. (2019)	15–30		25	26–30
Ukpata et al. (2024)	0–30		20	27–31
Adeyemi and Olowu (2017)	0–25		15	24–27
Olanitori et al. (2016)	10–30		20	25–29
Adepegba et al. (2016)	10–30		20	26–29
Ambrose et al. (2018)	0–30		20	25–28
Ajagbe et al. (2018)	15–30		25	27–30
Oladimeji et al. (2022)	0–25		15–20	24–27
Nwankwo and Okafor (2021)	10–30		20	26–29

3.5 Findings of the Study

The quantitative synthesis of the reviewed studies indicated that locally sourced soils can effectively serve as partial replacements for conventional river sand when proper characterization and grading are carried out.

The reviewed experimental data revealed that optimum replacement levels generally fall between 15–25%, with an average compressive strength of approximately 27 MPa achieved within this range. Nwankwo and Okafor (2021) similarly reported that lateritic soil replacement levels below 30% produced optimum compressive strength performance, whereas further increases in replacement percentage resulted in noticeable strength reduction due to excess fines and weaker cement–aggregate interaction. The analysis further showed that lateritic and well graded sandy soils produced the most favorable engineering performance due to their relatively low plasticity and improved particle packing characteristics. The observed reduction in compressive strength at higher replacement levels may be attributed to increased clay content and weaker interfacial bonding between soil particles and hydrated cement paste. Fine clay particles tended to absorb water and coat aggregate surfaces, thereby interfering with the formation of strong calcium silicate hydrate (C-S-H) bonds within the concrete matrix. Conversely, soils containing reactive silica and alumina may contribute to secondary pozzolanic reactions that improve matrix densification and strength development at moderate replacement levels. However, replacement levels exceeding 25–30% consistently caused reductions in compressive strength and workability because of increased clay and silt fractions.

3.6 Economic and Durability Considerations

Several reviewed studies highlighted the potential economic advantages associated with the use of locally sourced soils as partial replacements for river sand in concrete production. In many developing regions, particularly in areas where river sand must be transported over long distances, locally available soils may significantly reduce material transportation and procurement costs (Adetayo *et al.*, 2019). Experimental studies reported that partial replacement levels between 15–25% could reduce fine aggregate costs while maintaining acceptable compressive strength for normal structural applications. The economic benefits are primarily associated with reduced dependence on commercially mined river sand, lower transportation costs, reduced environmental degradation from sand mining and improved utilization of locally available materials. However, the long-term durability performance of soil modified concrete remained an important engineering consideration. Durability properties such as water absorption, permeability, shrinkage behavior, sulphate resistance, carbonation resistance and freeze thaw performance have not been extensively investigated in many of the reviewed studies. The presence of excessive clay particles may increase porosity and water absorption within the concrete matrix, thereby increasing susceptibility to cracking and durability deterioration under aggressive environmental exposure. Nevertheless, studies involving properly graded sandy and lateritic soils with low clay content reported acceptable durability behavior comparable to conventional concrete at moderate replacement levels. Therefore, although locally sourced soils demonstrated promising economic and environmental advantages, further long-term durability investigations and standardization are required before full scale structural implementation in critical engineering applications.

Table 5: Comparative economic benefits of soil based fine aggregate replacement

Material Type	Relative Material Cost	Transportation Requirement	Environmental Impact	Availability
Conventional River Sand	High	High in remote regions	High due to sand mining	Decreasing
Lateritic Soil	Moderate to Low	Low	Lower environmental impact	Widely available
Sandy Local Soil	Low	Low	Reduced environmental degradation	Abundant locally

4. Conclusion

This review critically assessed the suitability of locally sourced soils as alternative fine aggregates in concrete production with emphasis on engineering performance, sustainability and practical construction applications. The reviewed studies indicated that properly graded lateritic and sandy soils can effectively replace approximately 10–30% of conventional river sand without significant reduction in compressive strength. Most experimental investigations reported compressive strengths ranging from 24–30 MPa within this replacement range, demonstrating that soil modified concrete can satisfy requirements for several structural and non-structural applications when appropriate mix design and material characterization procedures are adopted. The performance of soil modified concrete was found to depend strongly on particle size distribution, plasticity, clay content and mineralogical composition of the soils. Well graded sandy soils and low-plasticity lateritic soils generally exhibited improved particle packing, lower water absorption and better durability characteristics compared with highly silty or clayey soils. In contrast, excessive clay and silt contents above

approximately 8–10% increased water demand, reduced workability and weakened the interfacial bond between aggregate particles and hydrated cement paste, resulting in reduced strength and increased permeability. The review further showed that soils containing reactive silica and alumina may contribute to secondary pozzolanic reactions and additional calcium silicate hydrate (C-S-H) formation, thereby improving matrix densification and strength development. However, despite promising mechanical performance, existing studies provide limited information regarding long-term durability and microstructural behavior. Important durability parameters including chloride penetration, sulphate resistance, carbonation, shrinkage and freeze thaw behavior remained insufficiently investigated. From an engineering and sustainability perspective, the use of locally sourced soils offers significant economic and environmental benefits through reduced dependence on river sand, lower transportation costs and mitigation of environmental degradation caused by excessive sand mining. Nevertheless, further durability studies, field performance evaluation and development of standardized specifications and design guidelines are necessary before widespread structural implementation can be fully recommended.

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