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Geopolymer Innovation in Construction: Environmentally Friendly and Sustainable Materials

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construction innovation;

Abstrak

Batu bata geopolimer adalah inovasi penting dalam industri konstruksi, yang mewakili pendekatan ramah lingkungan dan berkelanjutan. Bahan utamanya bersumber dari limbah industri, antara lain tailing tambang tembaga dan bijih besi, yang sering dianggap sebagai pencemar lingkungan. Proses produksi batu bata geopolimer melibatkan penggunaan bahan kimia seperti natrium silikat dan natrium hidroksida (NaOH) sebagai aktivator untuk membentuk ikatan polimer. Selain itu, berbagai limbah industri lainnya, seperti limbah keramik, batu bata tanah liat, dan limbah plastik, digunakan sebagai bahan formulasi untuk meminimalkan dampak terhadap lingkungan. Penambahan bahan pelengkap antara lain metakaolin, Ground Granular Blast Furnace Slag (GGBFS), Recycled Concrete Aggregate (RCA), Foundry Sand Waste (FSW), pasir terak, dan fly ash, semakin mendukung pengembangan sifat unik pada batu bata geopolimer. Metode produksi batu bata geopolimer mencakup berbagai teknik, antara lain ekstrusi, standardisasi, dan pemadatan tinggi hingga 100 MPa. Proses pembakaran pada tungku listrik merupakan tahapan krusial dalam pembentukan dan pembakaran batu bata dengan kekuatan dan daya tahan yang optimal. Selama tahap produksi, serat polipropilen dan geopolimer pengikat, seperti natrium, kalsium, dan amonium, digunakan untuk meningkatkan kohesi dan daya tahan batu bata geopolimer. Penting untuk memperhatikan sifat penyerapan air pada batu bata geopolimer, karena hal ini mempengaruhi kinerja dan daya tahan struktur yang dibangun menggunakan bahan ini. Penyerapan air dapat bervariasi tergantung pada formulasi bahan dan proses produksi. Beberapa faktor yang mempengaruhi penyerapan air antara lain waktu pemeraman, kandungan terak, persentase penggantian agregat, dan penggunaan serat polipropilen dan metakaolin. Batas penyerapan air tipikal untuk batu bata geopolimer tidak boleh melebihi 20% dari berat batu bata, dengan kisaran penyerapan awal yang dapat diterima yaitu 10-30 gram. Sifat fisiko-mekanik batu bata geopolimer juga menjadi fokus penelitian. Kuat tekan batu bata geopolimer merupakan salah satu parameter penting yang harus diperhatikan. Kekuatan tekan berkisar antara 5-60 N/mm2, dan dalam beberapa kasus, bahkan lebih tinggi lagi, memenuhi persyaratan standar. Faktor-faktor yang mempengaruhi kekuatan batu bata geopolimer antara lain rasio limbah minuman beralkohol dan keramik, kandungan alkali, persentase penggantian agregat dengan Agregat Beton Daur Ulang (RCA) dan Polyethylene Terephthalate (PET), serta proses produksi seperti pembakaran cepat dan hiperkompaksi. Selain itu, penggunaan lignosulfonat dan bahan tambahan lainnya, seperti serbuk debu marmer (MP) dan serbuk debu batu kapur (LP), juga dapat mempengaruhi sifat fisika-mekanik batu bata geopolimer. Penggunaan bahan kimia tambahan dan stabilisasi berperan penting dalam meningkatkan kekuatan dan daya tahan batu bata geopolimer. Stabilisasi kimia menggunakan semen, kapur, atau bahan pengikat lainnya dapat meningkatkan daya tahan batu bata

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secara signifikan. Selain itu, penelitian juga menyoroti penggunaan nanoteknologi sebagai bahan penstabil untuk meningkatkan ketahanan material batu bata.

Abstract

Geopolymer bricks are a crucial innovation in the construction industry, representing an environmentally friendly and sustainable approach. The primary ingredients are sourced from industrial waste, including copper mine tailings and iron ore, which are often considered environmental pollutants. The production process of geopolymer bricks involves the use of chemicals, such as sodium silicate and sodium hydroxide (NaOH), as activators to form polymeric bonds. Additionally, various other industrial wastes, such as ceramic waste, clay bricks, and plastic waste, are used as formulation ingredients to minimize environmental impact. The addition of supplementary ingredients, including metakaolin, Ground Granular Blast Furnace Slag (GGBFS), Recycled Concrete Aggregate (RCA), Foundry Sand Waste (FSW), slag sand, and fly ash, further supports the development of unique properties in geopolymer bricks. Geopolymer brick production methods encompass various techniques, including extrusion, standardization, and high compaction up to 100 MPa. The firing process in an electric furnace is a crucial step in forming and firing bricks with optimal strength and durability. During the production stage, polypropylene fibers and binding geopolymers, such as sodium, calcium, and ammonium, are used to increase the cohesion and durability of geopolymer bricks. It is essential to pay attention to the water absorption properties of geopolymer bricks, as this affects the performance and durability of structures built using this material. Water absorption may vary depending on the ingredient formulation and production process. Several factors that influence water absorption include curing time, slag content, percentage of aggregate replacement, and the use of polypropylene and metakaolin fibers. The typical water absorption limit for geopolymer bricks should not exceed 20% of the brick's weight, with an acceptable initial absorption range of 10-30 grams. The physico-mechanical properties of geopolymer bricks are also the focus of research. The compressive strength of geopolymer bricks is one of the important parameters that must be considered. Compressive strength ranges from 5-60 N/mm2, and in some cases, even higher, meeting standard requirements. Factors influencing the strength of geopolymer bricks include the ratio of grog and ceramic waste, alkali content, percentage of aggregate replacement with Recycled Concrete Aggregates (RCA) and Polyethylene Terephthalate (PET), and production processes, such as rapid firing and hypercompaction. In addition, the use of lignosulfonates and other additives, such as marble dust powder (MP) and limestone dust powder (LP), can also affect the physico-mechanical properties of geopolymer bricks. The use of chemical additives and stabilization plays an important role in increasing the strength and durability of geopolymer bricks. Chemical stabilization using cement, lime, or other binders can significantly increase the durability of bricks. Apart from that, research also highlights the use of nanotechnology as a stabilizer to increase the durability of brick materials.

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Introduction

Geopolymer bricks are an essential innovation in the construction industry that applies an environmentally friendly and sustainable approach. The main ingredients come from industrial waste, such as copper mine tailings and iron ore, often considered environmental pollutants [1]–[3]. The geopolymer brick production process involves using chemicals, including sodium silicate and sodium hydroxide (NaOH), which act as activators to form polymeric bonds [1], [2], [4]–[6]. Various industrial wastes such as ceramic waste, clay bricks, and plastic waste are also used as formulation ingredients to minimize environmental impact [7]. Addition of additional ingredients such as metakaolin, Ground Granular Blast Furnace Slag (GGBFS), Recycled Concrete Aggregate (RCA), Foundry Sand Waste (FSW), slag sand, and fly ash, also supports the development of special properties of geopolymer bricks [3], [5], [8]–[12].

Geopolymer brick production methods involve various techniques, including extrusion, standardization, and high compaction up to 100 MPa [6], [13]. The firing process in an electric furnace is a crucial method for forming and firing bricks with optimal strength and durability. In the production stage, polypropylene fibers and binding geopolymers such as (sodium, calcium, and ammonium) are used to increase the cohesion and durability of geopolymer bricks [6], [14].

It is essential to pay attention to the water absorption properties of geopolymer bricks, as this affects the performance and durability of structures built using this material. Water absorption may vary depending on the ingredient formulation and production process. Several factors that influence water absorption include curing time, slag content, percentage of aggregate replacement, and use of polypropylene and metakaolin fibers. [6], [10], [14]. The water absorption limit of geopolymer bricks should usually not exceed 20% of the weight of the brick, and the acceptable initial absorption range is 10-30 grams [3].

The physico-mechanical properties of geopolymer bricks are also the focus of research. The compressive strength of geopolymer bricks is one of the important parameters that must be considered. This compressive strength ranges from 5-60 N/mm2, even higher in some cases, and meets standard requirements [1], [15]. Factors influencing the strength of geopolymer bricks include the ratio of grog and ceramic waste, alkali content, percentage of aggregate replacement with Recycled Concrete Aggregates (RCA) and Polyethylene Terephthalate (PET), and production processes, such as rapid firing and hypercompaction [8], [10], [11]. In addition, the use of lignosulfonates and other additives, such as marble dust powder (MP) and limestone dust powder (LP), can also affect the physico-mechanical properties of geopolymer bricks [6].

The use of chemical additives and stabilization plays an important role in increasing the strength and durability of geopolymer bricks. Chemical stabilization using cement, lime, or other binders can significantly increase the durability of bricks [6]. Apart from that, research also highlights the use of nanotechnology as a stabilizer to increase the durability of brick materials [16].

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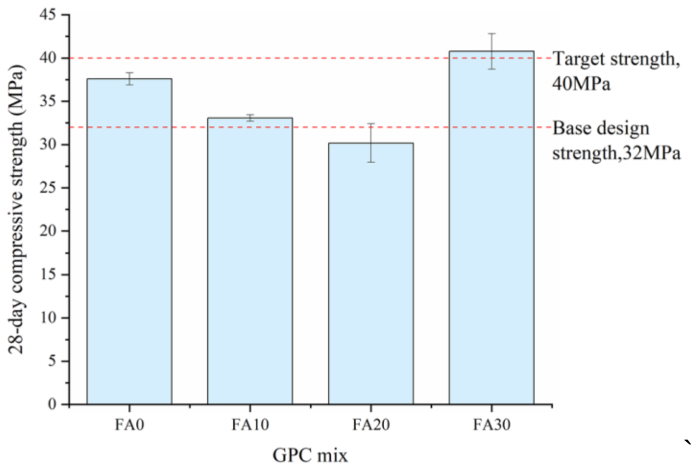
Results and Discussion

The successful application of geopolymer bricks in construction requires a holistic approach, taking into account technical, economic, and environmental aspects. Economic benefits, resistance to various environmental conditions, and potential for reducing waste and negative environmental impacts must be carefully evaluated.

Overall, geopolymer bricks are a promising innovation in the construction industry, integrating waste materials and modern production technology to create a more environmentally friendly and sustainable product. With further research and development, geopolymer bricks can become the primary choice in building sustainable and environmentally friendly future buildings.

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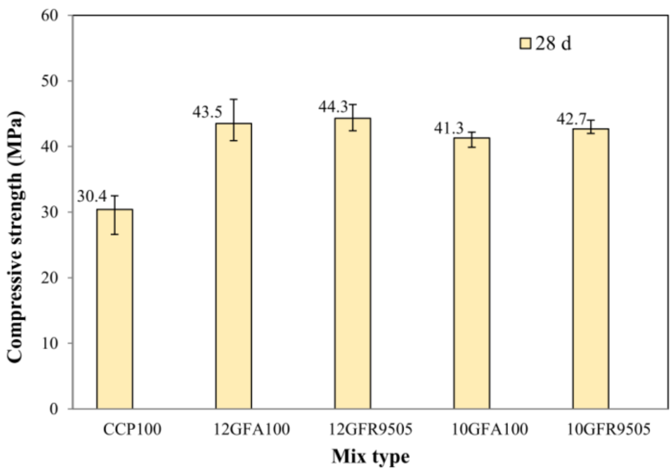
Gambar 1 menunjukkan kuat tekan campuran GPC selama 28 hari dengan empat jenis pengikat. Semua sampel lainnya mencapai kekuatan lebih dari 32 MPa, yang merupakan persyaratan kekuatan desain minimum untuk beton dasar perke`rasan kecuali untuk campuran GPC FA20. Hanya campuran FA30 yang mencapai kekuatan lebih dari 40 MPa,yaitu sekitar 41 MPa

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Gambar 2 menunjukkan kuat tekan campuran GPC selama 28 hari dengan empat jenis pengikat. Semua sampel lainnya mencapai kekuatan lebih dari 32 MPa, yang
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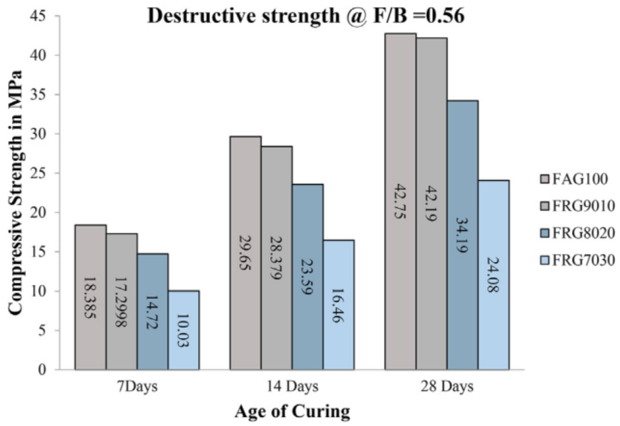
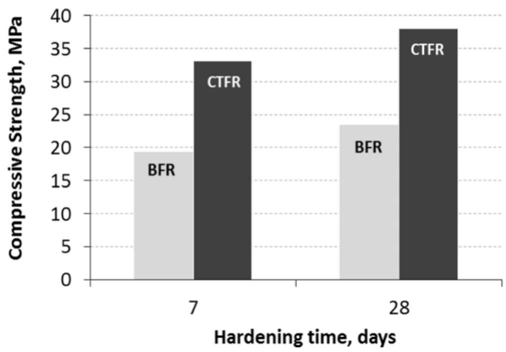
merupakan persyaratan kekuatan desain minimum untuk beton dasar perkerasan kecuali untuk campuran CCP100.



Gambar 3 menunjukkan nilai kemampuan kerja dan berat jenis beton geopolimer dengan peruntukan campuran yang berbeda-beda. Abu sekam padi tempat pembakaran batu bata mempunyai pengaruh yang besar terhadap kemampuan kerja beton geopolimer. Diketahui bahwa campuran beton geopolimer yang mengandung flyash kelas F (FAG) atau fly ash mengandung silika memiliki kemampuan kerja yang lebih tinggi dibandingkan jenis campuran lainnya.



Gambar 4, material geopolymers Brick Fire Resistant (BFR) and Ceramic Tiles Fire Resistant (CTFR) mengembangkan kekuatan tekan yang signifikan. Kekuatan tekan CTFR lebih tinggi dibandingkan BFR.

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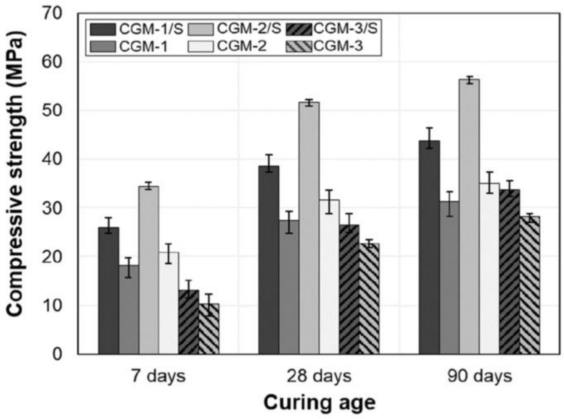

Gambar 5, hasil kuat tekan tertinggi diperoleh dari campuran berkode CGM-2/S untuk campuran tersubstitusi terak dan dari campuran berkode CGM-2. Hasil penelitian menunjukkan bahwa hasil kuat tekan 28 hari di atas 30 dan 50 MPa dapat dicapai dengan mortar yang seluruhnya berbahan dasar CDW dan tersubstitusi terak, yang terbukti lebih baik jika menggunakan beton struktural yang seluruhnya berbahan dasar CDW.

Conclusion

geopolymer bricks represent a remarkable and transformative innovation in the construction industry, driven by their environmentally friendly and sustainable approach. These bricks utilize industrial waste materials, such as copper mine tailings and iron ore, which are typically regarded as environmental pollutants, as their primary components. The production process relies on chemical activators like sodium silicate and sodium hydroxide (NaOH) to create the essential polymeric bonds.

Furthermore, geopolymer brick formulations incorporate a variety of industrial waste materials, including ceramic waste, clay bricks, and plastic waste, to minimize their environmental impact. Additional ingredients like metakaolin, Ground Granular Blast Furnace Slag (GGBFS), Recycled Concrete Aggregate (RCA), Foundry Sand Waste (FSW), slag sand, and fly ash further enhance the unique properties of these bricks.

The methods employed for geopolymer brick production encompass various techniques, including extrusion, standardization, and high compaction, often exceeding pressures of 100 MPa. The firing process in an electric furnace is instrumental in achieving the optimal strength and durability of these bricks. During production, polypropylene fibers and binding geopolymers (e.g., sodium, calcium, and ammonium) are introduced to enhance the cohesion and durability of geopolymer bricks.

Attention to the water absorption properties of geopolymer bricks is vital, as it significantly impacts the performance and durability of structures constructed using this material. Factors influencing water absorption include curing time, slag content, percentage of aggregate replacement, and the use of polypropylene and metakaolin fibers. The recommended water absorption limit for geopolymer bricks typically does

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not exceed 20% of the brick's weight, with an acceptable initial absorption range of 10-30 grams.

The physico-mechanical properties of geopolymer bricks, notably their compressive strength, are of paramount importance. Compressive strength typically falls within the range of 5-60 N/mm2, meeting established standards, and in some instances, even surpassing these standards. Factors affecting the strength of geopolymer bricks include the grog and ceramic waste ratio, alkali content, percentage of aggregate replacement (e.g., Recycled Concrete Aggregates and Polyethylene Terephthalate), and production processes such as rapid firing and hypercompaction. Additionally, the inclusion of lignosulfonates and other additives, such as marble dust powder (MP) and limestone dust powder (LP), can further influence the physico-mechanical properties.

Chemical additives and stabilization play a pivotal role in enhancing the strength and durability of geopolymer bricks. The use of cement, lime, or other binders as chemical stabilizers can significantly improve the bricks' durability. Moreover, research highlights the potential use of nanotechnology as a stabilizing agent to enhance the longevity of these materials.

The successful integration of geopolymer bricks into construction necessitates a holistic approach that considers technical, economic, and environmental aspects. The assessment of economic advantages, resilience in diverse environmental conditions, and the potential to reduce waste and minimize environmental impact are critical considerations.

In sum, geopolymer bricks exemplify a promising and sustainable innovation within the construction industry, ingeniously combining waste materials with modern production techniques to create environmentally friendly and durable building materials. With continued research and development, geopolymer bricks have the potential to become the primary choice for constructing eco-friendly and sustainable structures in the future.

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