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Application and Benefit Assessment of Sustainable Building Materials in High-Rise Building Design

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Abstract: With increasing environmental awareness, the use of sustainable building materials in modern high-rise architecture has become increasingly prominent. This paper provides a detailed analysis of Wood Chip Concrete Blocks (CBWC), exploring their application in high-rise building design, along with their environmental attributes, thermal performance, and structural integrity. Research indicates that CBWCs have a thermal resistance of R=5.26 m²K/W and fire resistance exceeding 180 minutes, significantly enhancing the building's energy efficiency and environmental friendliness. Simulation data reveals that the improved CBWC2 model, after partial filling and reinforcement, increased its peak horizontal force to 165.2 kN and reduced displacement to 9.99 mm, indicating enhanced structural stability. This study aims to use wood chip-reinforced concrete blocks to improve building energy efficiency and reduce carbon footprint while ensuring durability and safety, providing a sustainable material choice for future constructions.

Keywords: Sustainable Building Materials; Wood Chips; Concrete Blocks; Structural Stability.

1. Foreword.

Under the background of severe global environmental challenges and energy crisis, the development and application of sustainable building materials has become an important trend in the construction industry. Especially in the field of high-rise building design, the selection of appropriate building materials is not only related to the energy efficiency and environmental protection of buildings, but also directly affects the functionality and economy of buildings [1]. This paper focuses on an innovative sustainable building material-concrete block containing sawdust (CBWC), which aims to improve the environmental protection standards and energy efficiency of buildings by combining recycled wood with traditional concrete. In addition, through the optimization design of CBWC structure, we also find that it shows stronger structural stability under heavy load, which significantly improves the safety and durability of the building. The purpose of this paper is to show the application benefits of CBWC as a new sustainable building material in high-rise buildings. With scientific data support, it provides an effective scheme for the construction industry to reduce carbon footprint and enhance building performance, and also provides more green and sustainable material choices for future buildings.

2. Concrete Block Solution with Sawdust.

Table 1. Composition of concrete blocks containing sawdust

Material type	ratio
Scraps of wood	85%
Cement	10%
Polymer	5%

High wood content block is a prefabricated building component, which is made of a mixture of cement, water and mineralized wood chips. The production of substrates requires renewable resources, such as wood chips, and can take different forms. The wood used to make these components is waste wood made of old pallets and chips. The composition of wood chip concrete block is shown in Table 1.

Because the wood is mineralized and sealed by cement, it will not burn or rot, so the embedded carbon is permanently locked. The concrete block containing sawdust is completely recyclable, contains no toxic elements and is safe to the environment. Fig. 1 shows a concrete block containing sawdust with greater thickness and partially filled with concrete, and shows the texture of the material made of concrete and sawdust.



Fig 1. Concrete block with sawdust

The thickness of concrete blocks containing sawdust varies from 15 to 37.5 cm, depending on the type and use of the building: residential, apartment building, public building or industrial building [2].

This system combines all the advantages of wood and concrete, and has good thermal insulation performance and heat storage capacity. At the same time, the system has good water vapor permeability and can ensure the balance between indoor air temperature and relative humidity. The sawdust layer has advantages in thermal insulation performance and thermal storage capacity of concrete core, which in turn brings cost advantages to heating in winter or air conditioning in high temperature period [3]. For a standard concrete block

containing sawdust, the thickness is 375mm, the length is 500mm, the thermal insulation material is filled with 175mm, the height is 250mm, the heat transfer resistance of the unglazed wall is R = 5.26 m^2K/W, and the heat transfer coefficient of the external wall is U = 0.18 W/m^2K with plaster inside gypsum and plaster outside lime cement.

These blocks have 100% fire resistance REI 180; For plastered walls, the fire resistance is higher than 180 minutes. As for the bearing characteristics of these sawdust blocks, their characteristic compressive strength is equivalent to that of low-quality ceramic blocks, and their tensile strength is low [2]. By introducing an appropriate amount of reinforcement and effective anchorage, its ability to withstand tensile stress can be increased. As far as the bearing system is concerned, the load acting on the concrete block system containing sawdust is borne by the concrete core. The concrete core can be flat or reinforced, and as a placement method, it must be poured in the gaps of elements on site [4]. The mixing proportion of concrete is shown in Table 2.

Table 2. Mix proportion of concrete

Material	Radio
Cement	10%
Water	18%
Sand	25%
Broken stone	41%
Air	6%

3. Concrete Block Solution with Sawdust.

3.1. Solid Brick Wall

The response of solid brick wall to lateral load is studied and evaluated, including the initial state and the situation after reinforcement. The test wall size is 150cm × 150cm × 24cm, the average compressive strength of ceramic block is 10 n/mm^2, and the compressive strength of cement-based mortar is 13-16 N/mm^2. The tested wall is subjected to both vertical force continuously applied and horizontal force periodically applied by actuators. The experimental results show that the wall has the problem of insufficient seismic energy dissipation under the action of horizontal force, leading to diagonal cracks and damage. The strengthening method is to use high-strength metal fiber reinforced mortar [5], improving the bearing capacity and ductility of the wall and enhancing the earthquake energy absorption capacity. After strengthening, the bearing capacity of the wall increases by 80% and the displacement increases by two times, which proves that the ductility and seismic energy absorption capacity of the wall increase [6].

3.2. Ceramic Block Masonry Wall with Vertical Gap

The masonry wall composed of ceramic blocks with vertical cavities is studied, and a group of nine-faced walls, including simple masonry and masonry limited by columns, are tested. These elements are made of Porotherm 25 vertical hollow ceramic blocks, with the size of 375mm×250mm×238mm, the average compressive strength of 10 N/mm^2, and the compressive strength of cement-based mortar is between 5 and 6 N/mm^2. Elements made of simple masonry fail when the horizontal load is 105-140kN and the horizontal displacement is 5.4-11 mm. For elements made of masonry confined by piles, increased bearing capacity is observed under horizontal action, so failure occurs when the horizontal load is 200-230kN and the maximum horizontal displacement is 6.0 mm.

The reinforcement solution implemented is polymer composite reinforcement. The test shows that the recovery value of the maximum horizontal force is between 80% and 115%, and the recovery rate is between 50% and 80% for the maximum lateral displacement. The ductility of the wall strengthened with polymer materials is lower than that of the original wall [7].

3.3. Concrete Block Wall with Wood Chips

The research will focus on the concrete block wall containing sawdust with the size of 150 cm× 150 cm× 25 cm. The test procedure used will be similar to the other two cases mentioned above. The purpose of the test is to evaluate the behavior of the wall to lateral load. It is suggested to evaluate three groups of elements to improve the accuracy of the results. Compared with traditional ceramic blocks, these blocks have the advantage of using sawdust which is considered as a sustainable material.

4. Numerical Analysis

In this study, four numerical models are established to simulate the behavior of each proposed masonry type under lateral load. The analyzed elements are modeled as shell elements. On the boundary conditions of finite element model (FEM) in numerical analysis, the displacement and rotation of elements are blocked, and the embedding of simulated elements is simulated. On the upper part of the element, the rotation is also blocked, while allowing the displacement of the element in the horizontal plane. In addition, the numerical model is influenced by the general static vertical load between 150 and 200kN, and also by the static Riks type dynamic load, so as to simulate the effect of horizontal motion caused by earthquake. The discretization of the model is carried out at the whole element level in order to idealize the block-mortar assembly into a uniform medium with equivalent properties.

4.1. Solid brick wall URM

The numerical model is designed to prove that the hypothetical experimental model is correctly accepted in the calculation. Therefore, we use the average compressive strength of 10 N/mm^2 for solid brick masonry. In the analysis, we used a plastic strain of 0.0025, and the failure ratio R1=1.16； R2=1.08, and tensile reinforcement with displacement of 1.5. The elastic modulus of ceramic block is e = 13000 n/mm and Poisson's ratio is 0.25. The vertical force V=200kN and the increasing horizontal force are applied to observe the failure mode and time of elements. The analysis is carried out by finite element method using ABAQUS program. According to the numerical simulation, the maximum horizontal force recorded is H=144kN, and the maximum displacement at the top of the element is 10.64 mm.

4.2. Ceramic Block Masonry Wall with Vertical Holes VHB

For the wall made of Porotherm ceramic blocks with

vertical holes, a numerical model is developed to verify the experimental tests conducted in timisoara Civil Engineering and Installation Department. In the calculation, we use the average compressive strength of 10 N/mm^2 for the ceramic block wall with vertical holes. In addition, the plastic strain of 0.0025 is used in the analysis, and the failure ratio R1=1.16; R2=1.08, and tensile reinforcement with displacement of 1.5 was carried out. The elastic modulus of ceramic block is E = 16000N/mm^2 and Poisson's ratio is 0.25. Numerical simulation is carried out by applying a constant vertical force V=150kN and increasing horizontal force until failure occurs. The analysis results show that the displacement of the top of the element is 12.17mm when the wall is destroyed. Compared with the element displacement obtained from the experimental test, the final displacement is 11mm, which can be said that the results are almost the same, which confirms the authenticity of the experimental test.

4.3. Masonry Wall with Sawdust Concrete Block CBWC1

In order to numerically evaluate the wall made of concrete blocks containing sawdust, a numerical model which can replicate the mechanical properties of concrete blocks containing sawdust was developed. Therefore, the model has the following dimensions: 150cm×150cm×25cm, made of blocks with dimensions of 250 mm× 250 mm× 500 mm. After several simulations of the configuration of concrete blocks containing sawdust, it is decided to adopt the solution in Fig 2.

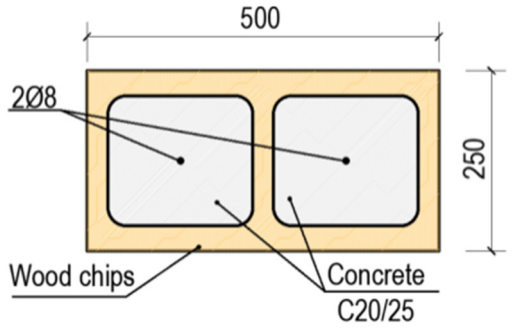


Fig 2. Configuration of CBWC2 block

The concrete block containing sawdust consists of 41.80% sawdust and 58.20% concrete. The block without concrete has a compressive strength of 2.5 N/mm², while the compressive strength of concrete is 20 N/mm², and the average strength used in calculation is 12.69 N/mm² In the analysis, we use a plastic strain of 0.0035, and the failure ratio R1=1.21； ; R2=1.08, and tensile reinforcement with displacement of 1.5 was carried out. The elastic modulus obtained from the equivalence of the two materials is E = 21,640 N/mm^2 and Poisson's ratio is 0.25. The numerical simulation is carried out by applying a constant vertical force V=200kN and increasing horizontal force until the fault occurs. The results of numerical analysis show that the displacement of the top of the element is 10.40mm and the maximum horizontal force recorded is H=177.8kN at the moment when the wall is destroyed.

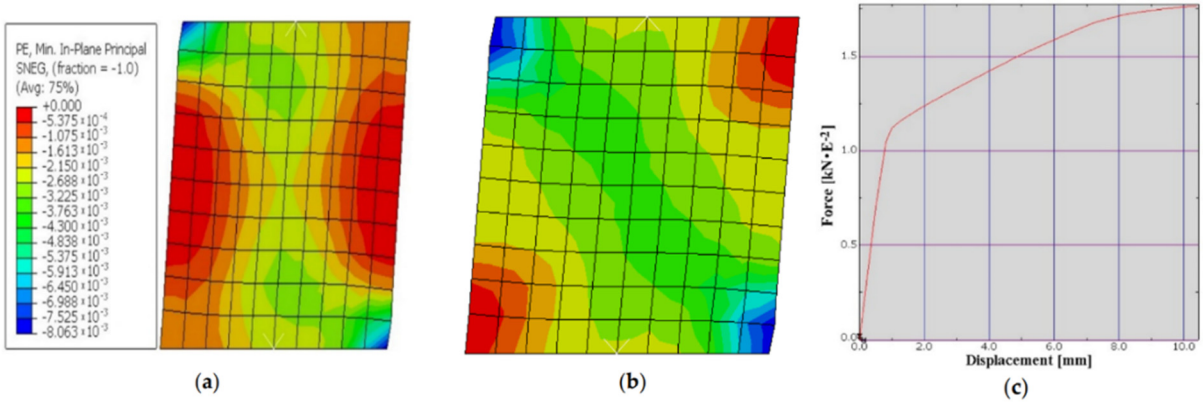


Fig 3. Numerical results of CBWC1 simulation

Fig. 3 shows the deformation of the top of the element (fig. 3a), the deformation mode and the area where the element failure will occur (fig. 3b), and the force-displacement diagram related to the numerical analysis (fig. 3c).

4.4. Masonry Walls with Sawdust Concrete Blocks CBWC2

The CBWC2 wall is composed of sawdust-containing blocks with different geometric configurations from the CBWC1 wall. Therefore, the model has the following dimensions: 150cm×150cm×37.5cm, made of blocks with dimensions of 375 mm× 250 mm× 498 mm. After several simulations of the configuration of concrete blocks containing sawdust, the solution shown in Figure 4 was decided. In this solution, the sawdust blocks were partially filled with C20/25 grade concrete, and two steel bars with a diameter of φ 8 and thermal insulation materials were added.

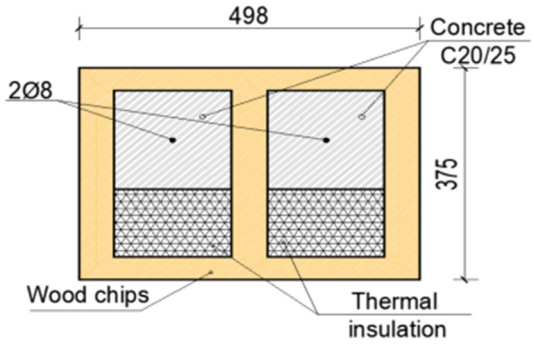


Fig 4. configuration of CBWC2 block

The concrete block containing sawdust consists of 45.98% sawdust, 32.05% concrete and 21.98% thermal insulation material. The average compressive strength used in the calculation is 7.63 N/mm^2. In the analysis, we used a plastic strain of 0.0035, and the failure ratio R1=1.16； . R2=1.08,

and tensile reinforcement with displacement of 1.5 was carried out. The elastic modulus obtained from material equivalence is E = 14215 N/mm^2 and Poisson's ratio is 0.25. The test procedure is the same as that of CBWC1 wall. The analysis results show that the displacement at the top of the element is 9.99mm and the maximum horizontal force recorded is H=165.2kN at the moment when the wall is destroyed.

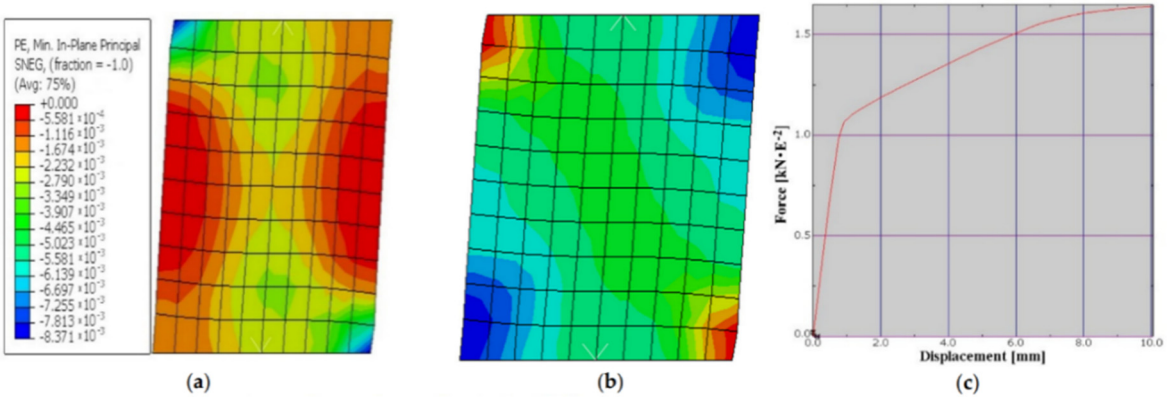


Fig 5. CBWC2 simulation numerical results

Fig. 5 shows the deformation of the top of the element (fig. 5a), the deformation mode and the area where the element failure will occur (fig. 5b), and the force-displacement diagram related to the numerical analysis (fig. 5c).

5. Concluding Remarks

This study shows the application of concrete block containing sawdust (CBWC) in high-rise building design, and evaluates its advantages in thermal efficiency and structural performance. The experimental and numerical simulation results show that CBWC has excellent thermal performance and structural stability, which significantly improves the energy efficiency and environmental protection of buildings. The improved CBWC2 model shows higher endurance and stability, which verifies the potential of sawdust reinforced concrete blocks in reducing carbon footprint and improving building durability and safety. This material has become an ideal choice for the sustainable development of high-rise buildings, and has brought new green solutions for modern architectural design. Therefore, CBWC is not only an environmentally friendly choice, but also an ideal material for sustainable development in high-rise buildings. Generally speaking, this study provides a more green and sustainable material choice for future buildings, and brings new ideas and solutions for modern architectural design.

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