The mechanical behavior of mortar cement mixing with palm sugar due to exposed to heat (high temperature)

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Abstract. Mortars will suffer damage if exposed to high temperatures. The selection of palm sugar as an added material for building purposes resistant to high temperatures is the aim of this research. This study provides an overview of the effect of high temperatures on mortar behavior. Preparation of specimens using cube mortar with length of 5 cm and carried out treatment at room temperature for 28 days. Mortar will be furnace at 250°C, 500°C, 750°C for 3 hours. In normal mortar, hair cracks seen at 500°C has seen this fine cracking indicates the mortar has been damaged. For heating temperatures of 750°C the crack size appears larger and deeper, the color of the mortar turns whiter and brighter, mortar has suffered severe damage. Mortars containing palm sugar 0.1%, 0.3% and 0.5% of the weight of cement did not experience cracking at 75°C, but only visible increase in pore size. The pore size is enlarged due to the gas pressure coming out of the cement matrix due to heating. Mortar with additional palm sugar still has a compressive strength of 50% at high temperatures 750°C.

1. Introduction

Mortar is an important construction material in buildings such as to attach bricks, plaster walls, attach ceramics and so on. Mortars consist of water, cement, fine aggregates and additives if needed. Water has an important role in the cement hydration process. Cement hydration is a chemical process in cement which produces heat and hardening process occurs.

The quality of the building depends on the quality of the mortar to be used. To maintain the quality of the mortar, the proportions of the ingredients must be precise and the order of work must be appropriate from the mixing of the ingredients, the molding process to the maintenance.

High temperature resistant building construction such as factory buildings, crematoriums, chimneys, fire stoves require special fire resistant building materials. Fire or high temperatures are dangerous elements in cement-based structures, namely concrete or mortar, high heat can damage the cement bonding matrix. The reduction in properties of mortar such as strength and durability occur due to variety of chemical and physical causes such high thermal effects and nature of materials [1]. Infrastructure fire safety design to minimize the structural damage and loss of lives during accidental fires. Structures are designed to bear high temperatures such as nuclear structures and industrial structures. Therefore, structures should be designed carefully to withstand high temperature [2].

Mortar failure due to high temperatures varies according to the nature of the material and the quality of the material used. Failure occurs due to loss of cement matrix bond strength, loss of compressive...
strength, and spalling of the mortar. The effect of high temperatures on mortar can result in changes in cement paste, aggregates, and interactions of these two constituents, which results in changes in the mechanical and physical characteristics of the mortar [3].

Mortars normal have limited heat intensity and long duration of fire. The high temperature intensity causes damage to buildings, such as cracks, cracks will develop with increasing temperature and duration of fire, and can even cause collapse. A lot of research has been done to find materials that can increase resistance to high temperatures.

Concrete heating makes the volume aggregate grow and contraction in the cement paste that surrounds it, consequently weakening the cement-paste bond. Damage to concrete is caused by cracks, which occur due to thermal imbalance between coarse aggregate and matrix. The impact due to high temperatures on concrete is a complex change in concrete that is the physical and chemical changes that occur in the cement matrix. Cement concrete is a composite consisting of two elements namely cement paste and aggregate which are substantially different: The effects that occur due to heated concrete are physical, thermal, and mechanical changes [1].

The concrete to high temperature, can undergo significant physico-chemical changes and loss of durability, throughout the appearing of crack, spalling, a gradual deterioration of the hardened cement paste [4]. Fire response of concrete structural members is dependent on the thermal, mechanical, and deformation properties of concrete [5]. Concrete having low thermal conductivity, the general fire testing standard, ASTM E119, does not permit fire testing of cement products unless the relative humidity in cement products is at or below 75 %. If not, concrete can experience significant spalling.

After the mixing process of the mortar with the added ingredients of palm sugar looks more runny, workability is better, but this only lasts for a moment the palm sugar absorbs into the cement layer. As a result the mortar dries faster so mortar printing must be done quickly, the gel layer on the sugar enters the cement core absorbs water quickly, the gel makes a layer or back that holds the water from evaporating so that it slows down the hydration process causing the cement mortar to harden longer, and the mortar does not need to be treated with soaking, the mortar only needs to be placed in a dry place on room temperature.

In general, added ingredients used in concrete or mortar can be divided into two, namely chemical additives (chemical admixed) and additives that are mineral (additive). Admixture added ingredients are added during mixing and placing casting while additive additives, which are mineral, are added when stirring is carried out. Palm sugar is a type of mineral added material. This added ingredient is added at the time of stirring. This added material is intended to increase the strength of the mortar after hardening.

Sugar-based added ingredients basically contain sucrose, which is a disaccharide composed of glucose and fructose units. The glucose, gluconate, and lignosulfonate content, will stabilize ettringite in the C3A-Gypsum system. Glucose will inhibit gypsum consumption and ettringite formation. The formation of this ettringite will cause the volume of concrete to expand so as to make the concrete break. Giving sugar-based added ingredients to the concrete mixture will result in a bond between the elements making up the concrete very strongly, especially because of the lignin content.

A sugar content of 0.06 % by weight of cement can increase the compressive strength of concrete by 3.62% at 28 days and delay the initial setting for 1,556 hours [6]. Palm sugar added dosage 0.1% of the weight of the cement is retarder because it can age the initial binding time 5.12 times slower than pasta without sugar mixture. At doses of 0.3 % and 0.5 % are accelerators because they accelerate the initial setting of cement 0.74 and 0.75 faster than without sugar added ingredients [7].

2. Research methodology
The research was carried out experimentally. Fine aggregate testing, compressive strength, furnace tests are carried out at the Material Technology Laboratory, Soil Mechanics Laboratory and Chemical Engineering Laboratory, University of Riau.

The specimens were demolded after 48 hour casting and cure room temperature. The method of testing the compressive strength of Portland cement mortar uses SNI-03-6825-2002 standard. The purpose of this method is to obtain mortar compressive strength at 28 days. This paper presents the
effects of high temperatures such as compressive strength, physical appearance of mortar with variations in the addition of palm sugar: 0, 0.1%, 0.2%, and 0.5% of the weight of cement after heating for 3 hours in the furnace at high temperatures 250°C, 500°C, and 750°C

2.1. Compressive strength
Compressive strength testing is done to determine the strength of the mortar. Compressive strength is the maximum force of unity of the area that works on the mortar, the mortar used is in the form of a cube with an area of 25 cm². The formula for calculating the compressive strength of test specimens is:

\[ F_m = \frac{P}{A} \]  

\( F_m \) = compressive strength of mortar (MPa)  
\( P \) = maximum compressive force (N)  
\( A \) = cross-sectional area (mm²)

2.2. Furnace
Furnace or also called the furnace is a device used for heating (Figure 1). The name comes from the Latin Formax, oven. Sometimes people call it clin. Almost all furnaces use liquid fuel, gas fuel or electricity as energy input.

![Figure 1. Furnace.](image)

3. Results and discussions

3.1. Compressing test
Normal mortars on 250°C heating do not experience a significant decrease in compressive losses only an average compressive strength loss of 1.07 MPa (5%). Significant pressure drop on combustion 500°C, normal mortar loses strength 9.33 Mpa (48%). And on heating the 750°C loses 12 MPa strength (61%). The effect of the temperature increase on the strength of the concrete is not significant up to a temperature of 250°C, but above the temperature of 500 °C the concrete will lose strength significantly. At a temperature of 400°C hard concrete will hydrate water loss in Ca(OH)₂ free and will leave CaO [8]. Increased temperature results in water evaporation, dehydration of C-S-H gel, calcium hydroxide and calcium aluminate decomposition. When the temperature threshold value of 500°C is passed the concrete is considered to be totally damaged because the compressive strength of the concrete drops by 50% to 60% [1].

Mortar with added palm sugar 0.1%, 0.3% and 0.5% at 250°C experienced a decrease in compressive strength: 5%, 4% and 31%. Significant decreases in strength occur at temperatures of 500°C decreases by 28%, 13% and 42%. And for temperatures of 750°C the decrease is still above 50%, namely: 42%, 46% and 49%. This proves that mortar with palm sugar added material is superior compared to mortar without using palm sugar added material. The magnitude of the decrease in strength can be seen in Figure 2.
3.2. Exposes high temperature

Normal mortar if subjected to high temperatures will experience damage in Figure 3 looks mortar with heating for 3 hours at 250°C temperatures have not occurred cracks. Changes taking place in concrete during heating temperatures 80°C – 150°C ettringite dehydration C-S-H gel dehydrati, 150°C - 170°C gypsum decomposition 9CaSO₄-2H₂O): physically bound water loss [1].

![Figure 3. Mortar normal highting temperature 250°C.](image)

Mortar normal heating temperature 500°C Figure 4. has seen cracks, which indicates the mortar has experienced damage. Cracks occur because trapped gas cannot leave the material pressing out by damaging the cement bonding matrix. Heating temperatures 400-500°C breakup of siliceous aggregate critical temperature of water [1].

In testing with a high temperature of 750°C in Figure 5. the crack appears larger, the pore space is larger and the color of the mortar turns whiter and brighter, indicating that there has been a significant change in the chemical composition of the cement. In this heating the mortar has experienced severe damage and the structure cannot be used. Heating temperatures 573-540°C portlandite decomposition Ca(OH)₂ → CaO+H₂O. Second phase of the C-S-H decomposition [1]. The effects of high temperature are visible in the form of surface cracking and spalling [2].

![Figure 2. Decrease in strength effect high temperature.](image)
Mortars with added sugar palm doses of 0.1% (Figure 6), 0.3% (Figure 7) and 0.5% (Figure 8) do not experience cracking for all heating temperatures of 250°C, 500°C, 750°C. And here it is only displayed for combustion temperatures of 750°C (Figure 6). Only an increase in pore size becomes larger. With the increasing heating temperature of the mortar pores getting bigger, with added ingredients palm sugar makes the mortar more dense, the more doses of palm sugar the fewer mortar pores [9].

Figure 4. Mortar normal hightening temperature 500°C.
Figure 5. Mortar normal hightening temperature 750°C.

Figure 6. Mortar doses 0.1% palm sugar hightening temperature 750°C.
Figure 7. Mortar doses 0.3% palm sugar hightening temperature 750°C.

Figure 8. Mortar doses 0.5% palm sugar hightening temperature 750°C.
The thermal properties of concrete/mortar are more complex than most materials because they consist of composite materials whose constituents have different properties, the properties of which depend on humidity and porosity. High temperature exposure affects mechanical and physical properties. The change in properties due to high temperatures undergoes three phases: (1) transformation phase (for example, free water loss at 100 °C, decomposition of calcium hydroxide at 450°C, and quartz crystal transformation at 573°C), (2) pore structure develops (for example: the volume and surface of the pore increase to a temperature of 500°C and then decrease with a further increase), and (3) the thermo-hygro-chemo-mechanical process (for example, the temperature gradient causes thermal stress, chemical changes that affect pore pressure and structure) [10]. The exposure of concrete or cement mortars to fire or elevated temperatures affect the mechanical, a change also occur in the pore structures, leading to cracking and spalling [11].

4. Conclusion
From the results of studies that have been carried out, it can be concluded that palm sugar added ingredients have been proven to reduce damage to the structure when exposed to high temperatures, because having anti-crack properties is proven at a dose of palm sugar 0.1%, 0.3%, 0.5% of the weight of cement when subjected to high temperatures. Mortar with added ingredients of palm sugar still has strength above 50% at 750°C

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