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# COMPRESSIVE STRENGTH OF TYPE III GYPSUM MIXED WITH WATER OF DIFFERENT WATER HARDNESS LEVEL
## (Research report)

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***ABSTRACT***
***Background:*** *Fabrication of study model to replicate oral dental tissues are needed in dentistry. Type III gypsum is one of gypsum types that is often used to make cast model or die. One of type III gypsum property is compressive strength, which is an ability of the material to resist fracture. Choosing the use of water type should be considered due to final quality of the model and the die. Three different types of water based on water hardness were used in this study* ***Purpose:*** *to analyze the effect of peat water, tap water and aquades water hardness to compressive strength.* ***Method:*** *This research was pure experimental research design with the post-test only and control design. dental stone or type III gypsum were mixed with water from peat water, tap water and aquadest (as a control), water hardness were examined. Twenty four die stone were made to cylinder with size 40 mm in height and 20 mm in diameter based on ISO 6873:1998* for compressive strength test. ***Result:*** *The result of One Way Anova test and Post Hoc Bonferroni test was p= 0.000 (p <0.05) showing a significant difference among all groups. The mean value of type III gypsum compressive strength based on water hardness was 12.66 MPa for aquadest (soft); 9.71 MPa for tap water (hard) and 7.40 MPa for peat water (very hard).* ***Conclusion:*** *there were significant differences of water hardness of peat water, tap water, and aquadest to type III gypsum compressive strength.*

***Keywords****: compressive strength, peat water, tap water, type III gypsum, water hardness*

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## INTRODUCTION

The use of gypsum has been widely used in dentistry to replicate the anatomical structure of the dental and oral cavity and applied for clinical or laboratory work.[1,2] Gypsum is a mineral that is mined from various parts of the world and also a by-product formed by the results of several chemical processes. Chemically, the gypsum used for dental purposes is calcium sulfate dihydrate ($CaSO_4.2H_2O$).[3]

According to American Dental Association (ADA) specifications No. 25, dental gypsum consist of five types which is type I-V. Type III Gypsum known as dental stone is one type of gypsum that is often used to make dental model (cast model or die) due to high strength of fracture and abrasive and also has sufficient strength for the construction of acrylic denture base.[1,2,3] One of mechanical properties of type III gypsum is compressive strength, namely the ability of the material to resist fracture. Based on the specifications of American Dental Association (ADA) specifications No. 25, type III gypsum has a compressive strength of one hour after setting, ie a minimum of 20.7 MPa, but not exceeding 34.5 MPa. Variance of compressive strength value are determined by ratio powder and liquid (water).[2,4]

Dental gypsum powder needs to be mixed with water for manipulation. Dentist commonly use tap water as water sources to manipulate gypsum.[5,6] How ever, there were variaton of mineral content in tap water of the city.[6] Tap water sources are different in all regions, as well as water sources obtained in Banjarmasin city, Indonesia. The

limited access of clean water makes river water in the Banjarmasin area, for example, river water in Barito Kuala are used by the community to fulfill their daily needs, evenmore dentist for clinical use. The quality of raw water from certain regions are based on the chemical properties of the water which is the content of ions presented in water or commonly called water hardness.[5] One chemical factor that may improve water quality is water hardness. Water hardness is a term used to determine the number of ions contained in the water, especially the quality of sulfates, carbonate salts, calcium, and magnesium.[7,8,9]

The selection of water type may influence the final quality of the dental model.[10,11] There were study proved that water hardness may affect the setting time, compressive strength, and surface hardness on type IV gypsum, [12] Other studies have also showed that the high and low strength of gypsum dentistry is influenced by the role of ions contained in hardness of several types of water used. Ions contained in the hardness of some of these water types can act as accelerators and retarders. Addition of retarder and accelerator materials will reduce the wet strength and also dry strength of gypsum products, this is related to the chemicals that added therefore affect the purity of the mixture of gypsum products and may cause uneven crystallization of gypsum also reduce inter-crystalline cohesion bonds.[2] Until now, there is still a little information about the effect of hardness of water on the compression strength of type III gypsum, thus it is necessary to do the research to determine the compression strength of type III gypsum based on the water hardness level that used for gypsum manipulation.

## MATERIAL AND METHODS

The research is a true experimental research with post test only and control group design. The sampling type is simple random sampling.[13,14] Sampling of Anjir Pasar river water (peat water) and Anjir-Muara Pasar tap water are using a Horizontal Water Sampler tool then the hardness level of each water type are measured at the chemical laboratory of the Faculty of Engineering, University of Lambung Mangkurat with EDTA titration method. The test result for water hardness value then converted to hardness level according to American Society of Agricultural Engineers (S-339) and the Water Quality Association (WQA). 24 samples of type III gypsum samples were fabricated for three group : peat water, tap water and aquades based on the water hardness level, 8 sample for each group. Type III gypsum powder was weighed using analytical scales for 100 grams, while the water used was measured using a measuring cup for 50 ml. Type III gypsum powder is mixed with water into the rubber bowl stirring for 60 seconds / 120 times rotation until a smooth mixture is obtained. Gypsum dough is placed in a cylindrical mold with a diameter of 20 mm and a length of 40 mm then place the mold on the vibrator. After 1 hour the sample is released and the sample is allowed to harden completely for 24 hours.

Compressive strength is tested using Universal Testing Machine by applying compressive load to the samples until it breaks, compressive test according to the provisions of ISO 6873: 1998 for dental gypsum. The results of type III gypsum compressive strength in kgf units are then converted to MPa using the formula:

□ □ = F/A= N/m2 or MPa

Abbreviation :

F = The amount of force that can be received by the specimen → 1 kgf x 9,8 m/s2= N

A = Cross-sectional area of specimen → πr2 (mm2)

Compressive strength values were obtained then analyzed by One-Way ANOVA test with 95% confidence level (α = 0,05) and post hoc Bonferroni.

## RESULT

Test results for hardness level of the peat water, tap water and Aquadest can be seen in table 1.

Table 1. Water hardness level of the peat water, tap water and Aquadest

| Group | Water hardness value | Hardness level |
|---|---|---|
| peat water | 166 mg/l | hard |
| Tap water | 322 mg/l | Very hard |
| Aquadest | 0 mg/l | Soft |

Based on table 1 water hardness value of peat water (Anjir river water) and tap water (Anjir-Muara Pasar) are higher than the aquadest hardness value. Tap water has the highest water hardness value and categoryzed very hard level also aquadest has the lowest water hardness value and categoryzed soft level.

The mean and standard deviations of compression strength value of type III gypsum manipulated with peat water, tap water and aquadest can be seen in Table 2

Table 2. The mean and standard deviations of compression strength value of type III gypsum

| Group | Mean ± Standard Deviation (MPa) |
|---|---|
| peat water | $7,40 \pm 0,69^{A}$ |
| Tap water | $9,71 \pm 0,60^{B}$ |
| *Aquadest* | $12,66 \pm 1,01^{C}$ |

*value with different superscript letter show significant difference at $p<0.05$.
Post Hoc LSD
*Significant ($P < 0.05$).

Based on table 2, it can be seen that type III gypsum mixed with peat water and tap water exhibits a lower mean value of compressive strength compared to type III gypsum mixed with aquadest. Type III gypsum mixed with peat water has the lowest mean compressive strength value. Table 2 also showed that there were significant differences in all treatment groups.

**DISCUSSION**

The strength of gypsum products has been shown as a compressive strength to withsatnd the force. The strength of the gypsum increases rapidly as a hard material after the initial setting time. Type and amount of water mixed with gypsum for manipulation may affect the strength of gypsum. One of the factors that influence the strength of gypsum compressive strength is the ratio of water / powder.[2,3] According to Sakaguchi RL (2009) the ratio of water / powder ideal for type III gypsum is 0.27-0.32 which can produce the highest compressive strength.[3] This study using the ratio of water 50 ml and powder of type III gypsum 100 g, that is why the compressive strength value in the study not exceeding 13 MPa. The results of this study are in accordance with Sakaguchi RL (2009), the use of 50 ml water and 100 g gypsum powder will produce a compression strength of 10.5 MPa. This is due to the more absorption of water result in the more water molecules in the space boundary area between the crystals which causes the compressive strength of the gypsum to be weak, moreover the space between the crystals is getting bigger. Conversely, when the gypsum contains a low moisture so the crystal boundary area will form space. Over time, these spaces will decrease because these crystals will form a single unit which may cause the gypsum to become stronger.[3]

According to Anusavice KJ (2004) the addition of retarder or accelerator materials may reduce the wet strength or dry strength of gypsum products.[2,4] River water contains aquatic organisms such as plankton and other organisms.[15] The presence of plankton, $CO_2$ organic compounds will continued to form carbonic acid compounds ($H_2CO_3$) then change the gypsum chemical formula which was originally $CaSO_4$. $^1/_2H_2O$ will change to $CaSO_4 + H_2CO_3 \rightarrow CaCO_{3(s)} + H_2SO_{4(aq)}$. The reaction from gypsum and river water is $CaCO_{3(s)}$ and $H_2SO_{4(aq)}$. Carbonic acid ($H_2CO_3$) which is present in the soil water may dissolve $CaCO_{3(s)}$. This is the reason there is a decrease in strength on gypsum material mixed with water containing carbonic acid ($H_2CO_3$).[2,15]

Based on Table 2 it is shown the level of water hardness, the compressive strength value of gypsum manipulated with the peat water PDAM are lower than compressive strength value of gypsum with aquadest, this was due to the mineral content in the water hardness of peat water were higher than aquadest and also increasing in ion and salt concentrations dissolved in water mixing result in no growth of gypsum crystals, therefore there were lack of crystal cohesion. Reducing in interlocking between crystals result in less resistance to external pressure.[4,16] Decreased compression strength of type III gypsum manipulated with peat water and tap water may be due to the role of minerals and ions contained in hardness of the water. This study result is inline with the study of Roy et al (2010) stated that ion contained in mixing solution may alter the gypsum crystalline structure that could affect the gypsum crystals ability to intermesh. The role of ions contained in mixing solution determine the strength of dental gypsum, therefore it can be act as accelerators and retarders. Adding an accelerator or retarder may reduce compression strength, by increasing chemicals, intercrystalline space are occupied with these chemicals therefore reducing intercrystalline cohesion and result in poor intercrystalline links.[2,3,5]

Vyas R et al (2008) study also support our study, it is stated that gypsum added with chemicals produced lower compressive strength compared to the control group that was not added with chemicals. Chemicals are added as function to increase the rate of the reaction, so it is possible that the reaction occurs quickly therefore some hemihydrate crystals are not entirely formed into dihydrates and result in weak gypsum products.[17] This is also inline with the study conducted by Abdelaziz KM et al (2002), showed that there were increase in the size of the dihydrate crystals and porosity in the gypsum group added with chemicals.[18]

The highest value of compression strength is found in the gypsum with aquadest group which has the lowest hardness value. This can be attributed to the content of aquadest which has no minerals so aquadest provide a regular crystalline

form, relatively not porous, and more dense. Water hardness affects the compressive strength of type III gypsum due to mineral ions contained in the water, therefore the use of water which has a mineral content may reduce compressive strength. This is consistent with the research conducted by Mussa L (2010) stated that minerals contained in water may decrease in compressive strength.[4,17,19]

Jayaprakas (2014) states that the higher the water hardness value result in the lower compressive strength value of gypsum [12,16] However, the opposite result is obtained in this study. The lower value of the water hardness of the peat water (166 mg / l) compared to the value of the water hardness level of tap water (332 mg / l), yields the compressive strength of type III gypsum manipulated with peat water (7,41 MPa) is lower than compressive strength value of type III gypsum manipulated with tap water (9.7 MPa). This is likely to occur due to variations in the concentration of ions and salts higher in peat water, result in the compression strength value obtained to be lower than tap water.[6] Aquadest is recommended to be used as mixing water for manipulation of type III gypsum to produce dental model. Based on the study, it can be concluded that there were significant differences of water hardness of peat water, tap water, and aquadest to type III gypsum compressive strength.

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