COMPRESSIVE STRENGTH OF TERMITE MOUND AND LIME BLENDED CEMENT MORTAR SUBJECTED TO ACIDIC ENVIRONMENT

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Abstract
This study investigated the compressive strength of 50 x 50 x 50 mm termite mound cement and sand mortar made from mixes containing lime,. Mix ratios (1:4 and 1:6) and percentage replacements of cement with lime and termite mound in the order of 0%, 10%, 20%, 30%, 40%, and 50% were used. A total of 360 cubes were cast and cured in water. The specimens were also cured in 1% and 3% solution of tetraoxosulphate vi and trioxonitrate v acid for a period of 7, 14, 21, 28 and 56 days using water binder ratio of 0.65. Test results revealed that the compressive strength of the mortar cubes increases with age but decreases with increasing percentage replacement of cement with lime and termite mound when cured in water while the compressive strength decreases with age and decreases with increasing percentage replacement of cement with lime and termite mound for the specimens cured in acid. The compressive strength of the sample cured in tetraoxosulphate vi acid (H_2SO_4) is higher than that of trioxonitrate v acid (HNO_3).

***Keywords*:** Acid environment, building materials, compressive strength, percentage replacement, termite mound,

Introduction

The increase in the cost of building materials are responsible for the current short fall in the provision of adequate housing in all part of Nigeria both urban and rural areas (Lasis *et al.,* 1990). The major challenge to the inaccessibility of the average Nigerian to affordable housing is largely predicted on the colossal cost of conventional building materials. Since building materials account for between 40-60% of the total construction cost as reported in literature by (Ayangade *et al.,* 2004; Olanipekun *et al.,* 2005).

Mortar is a mixture of cement and sand (fine aggregate). The constituent are usually mixed together with water to a plastic paste. It is used in building construction for binding construction blocks such as sandcrete block, glass block, bricks etc. It can also be used for plastering and rendering purposes.
Basic conventional building materials like cement and sand are becoming increasingly expensive to obtain because of high cost incurred in cement production, sand excavation process, pre-treatment and transportation.

In a view of producing buildings that are more environmentally friendly and also affordable in term of construction cost, researchers have been working tirelessly on how the locally available materials can be utilized to reduce the use, or replace the position, of the conventional building materials, most especially, Portland cement (Olusola and Adesanya, 2004).

The provision of housing is governed by the need for shelter among other factors and according to Fitch and Branch (1960); the need for shelter must be met by materials that the environment can afford. The materials should be available, sustainable and environmental friendly (Olusola, 2005). Besides, the building system derived from such materials must allow participation from the community and thereby improving the cash economy of that community. This is what Adegoke and Ajayi, (2003) referred to as appropriate technology. Examples of readily available local materials that can be used for cement replacement are volcanic ash, corncob ash, sawdust ash, rice husk ash and termite mound and conventional sand replacement materials such as erosion sand and laterite.

Every concrete structure is expected to perform its intended functions through the expected life time of the structure. Concrete subjected to environmental condition may result in premature failure or severe damages this is a major concern to engineering professional. Acid attack my damage concrete structures depending on the concentration and the type of acid. Some acids such as oxalic acid, are considered harmless, while weak solutions of some acids have significant effects (Bassel *et al.,* 2012). Acids generally necessarily attack and leach away the calcium compounds of the paste, they may not readily attack certain types of aggregates, such as siliceous aggregates. Calcareous aggregates often react readily with acids. However, the sacrificial effect of calcareous aggregates is often a benefit over siliceous aggregate in the mild acid exposures or in area where water is not flowing (Chang *et al*., 2005). With calcareous aggregate, the acid attack the entire exposed concrete surface uniformly, reducing the rate of attack on the paste and preventing loss of aggregate particles at the surface. Also, calcareous aggregate tend to neutralize the acid, especially in stagnant locations. This paper presents the compressive strength of termite mound lime blended cement mortar as partial replacement for cement in mortar subjected to acidic environment.

Termite mounds are available all over the world. However, the availability and distribution depend on soil and vegetation, climatic features and presence of water. In Nigeria, the most dominant species of mound building termites are the wood – feeding and the fungus growing *Macrotermes bellicosus*and the grass – harvesting *Trinevitermes* germinates. However, *M. bellicosus* constitute the dominant species and has a wider distribution in the southwestern zone of the country (Olusola *et al* 2006). A survey distribution of termites, hence termite mound, has revealed that certain species are restricted to a particular vegetation zone while some are distributed all over the zones. The rain forest appears to have more dominant species.
M. bellicosus hills, from which the termite mound soil samples taken for this test were taken, are large cathedral – like mounds up to 8m in height with an extension below ground central nest system. Collins (1981) and Kang (1978) reported about 6.4 mounds per hectare of *M.bellicosus* in the Nigerian Savanna and 17 mounds per hectare in the more humid Southwestern zone, respectively. Termite mound is a waste product with no competitive use and often destroyed by farmers.

The pile of earth made by termites resembling a small hill is called a termite mound. It is made of clay whose plasticity has further been improved by the secretion from the termite while being used in building the mound. It is therefore a better material than ordinary clay in terms of utilization for moulding (Odumodu, 1991). Termite mound has been reported to perform better than ordinary clay in dam construction (Yohanna *et al.,* 2003). The clay from termite mound is capable of maintaining a permanent shape after moulding. Termite mound clay has been considered for use in silos construction because of its plasticity and less prone to crack when compared with ordinary clay. Heat treated termite mound clay units are resistance to wear, abrasion and penetration by liquids (Parker, 1998). Termite mound clay has low thermal conductivity and expectedly should reduce solar heat flow into building enclosure and regulate temperature flunctuations within the storage environment (Adegunloye, 2007). Given its observed availability and its proposed use as a partial replacement for cement, the sustainability of termite mound is guaranteed. Lime to be used for this research is calcium hydroxide $Ca(OH)_2$ normally sold in commercial quantities in urban centres of the country.

Lime, a traditional modern material, has excellent plasticity and water retentivity, but it is slow in strength and slow to cure. Lime putty is made by slaking quicklime which is allow it to age, it is a quality product but the aging process is time consuming. As a result the more convenient dry hydrated lime is generally used.

l samples are uniformly graded and are suitable for making good mortar.
The initial moisture content test carried out indicated that water contents of 0.74% and 2.20% for sand and termite mound respectively. This indicates that the termite mound has a higher water retention capacity than soft sand.

Materials and Methods
The termite mound used was obtained in sold form. It was grinded and sieve with a 75 µm sieve. The sample was then subjected to chemical analysis for determination of the oxide content The analysis was carried out using X-Ray Fluorescent Analyser called Total Cement Analyser (Model ARL 9900 XP), connected directly to a computer system. The result of the chemical analysis is as presented in Table 1. The fineness moduli of the soil materials used were calculated as 2.13 for soft sand and 2.09 for termite mound. These values indicate fine aggregate of medium grading. The coefficient of uniformity Cu for both sand and termite mound. were obtained as 4.37 and 3.00 respectively. The values show that the soil samples are uniformly graded and are suitable for making good mortar.

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Table 1: Chemical Composition of Termite Mound

Material Constituent	Percentage Composition (%)
SiO_2	70.78
Al_2O_3	15.78
Fe_2O_3	5.69
CaO	-0.91
MgO	-0.60
SO_3	-0.12
K_2O	2.16
Na_2O	0.27
Mn_2O_3	0.02
P_2O_5	0.03
TiO_2	0.67
Cl_2	0.00
C_2S	697.52
C_3S	-660.73
C_3A	16.92
C_4AF	66.74
SR	0.97
AR	0.93
LSF	-0.34
SUM	83.76

Table 2: Chemical Composition of sand

Material Constituent	Percentage Composition (%)
SiO_2	99.00
Fe_2O_4	0.05
Al_2O_3	0.15
Ti_2O_5	0.05
CaO	0.06
MgO	0.05
LOI	0.09

Table 1 showed the results of the analysis of the chemical composition of a termite mound sample used while Table 2 showed a typical chemical analysis of soft sand. Tables 1 and 2 revealed that SiO_2 forms 99% of soft sand and about 70.78% of termite mound. This implies that soft sand is almost a pure quartz material. The results also showed that all samples of termite mound had combined percentages of silica (SiO_2) and Alumina (Al_2O_3) of more than 70%, a requirement of which a good binder should meet (Syagga *et al.,* 2001; Pekmezei and Akyuz, 2004 and Justnes *et al*., 2005). The requirements of ASTM C 618 for a combined SiO_2+ Al_2O_3 + Fe_2O_3 of more than 70% was also satisfied (Siddique, 2004). Thus, termite mound is a suitable material for use as a pozzolans. The quantity of silica was found to be higher, greater than 50%, this may be due to siliceous parent rock granite gneiss and charnockite, which were rich in siliceous minerals such as feldspar and quartz. The presence of Silica, Alumina and Iron is responsible for the formation of cementitious products when they react with lime in the presence of water. All the aggregates thereby conformed to the British Standard Specification BS EN 1097. The cement type used was Dangote Portland cement produced in Obajana factory, Kogi State, Nigeria and conformed to BS EN 197-2000.

To evaluate the strength characteristics of the mixtures, the compression test was carried out on the cube specimens (50 x 50 x 50 mm) by a 2000 KN capacity testing machine in accordance with ASTM C39 where two mix ratios were used (1:4 and 1:6). A total of 360 cubes were cast for the six levels (0%, 10%, 20%, 30% 40% and 50%) of replacement of cement with termite mound and lime. The strength measurements of concrete were performed at the ages of 7, 14, 21, 28, and 56 days. Three specimens were tested at each testing age.

The 50 mm cube moulds conforming to BS EN 12390 – 1:2000 specifications were used. The moulds were thoroughly cleaned and coated with used engine oil before casting to ensure easy demoulding and smooth surface finish. The wet mixture was cast into moulds immediately after mixing with hand trowel. The moulds were filled in two layers of 50 mm each, compacted using the compaction rod (25 mm diameter steel rod), the minimum of 25 strokes uniformly distributed over its surface during casting as stipulated by the requirements of BS EN 12390 –2, and 3:2000. The top of each mould was smoothened and levelled and the outside surfaces cleaned. The mould and their contents were kept in the curing room at temperature of 27 ± 5^0C and relative humidity not less than 90% for 24 hours. Demoulding of cubes took place after 24 hours and the specimens were transferred into a water bath maintained at 27 ± 5^0C in the curing room. Some of the specimens were transferred into solutions 1% and 3% of trioxonitrate V acid HNO_3 and Tetraoxosulphate VI acid H_2SO_4. Compressive strength were determined at curing age 3, 7, 28 and 56 days in-line with the code specification.

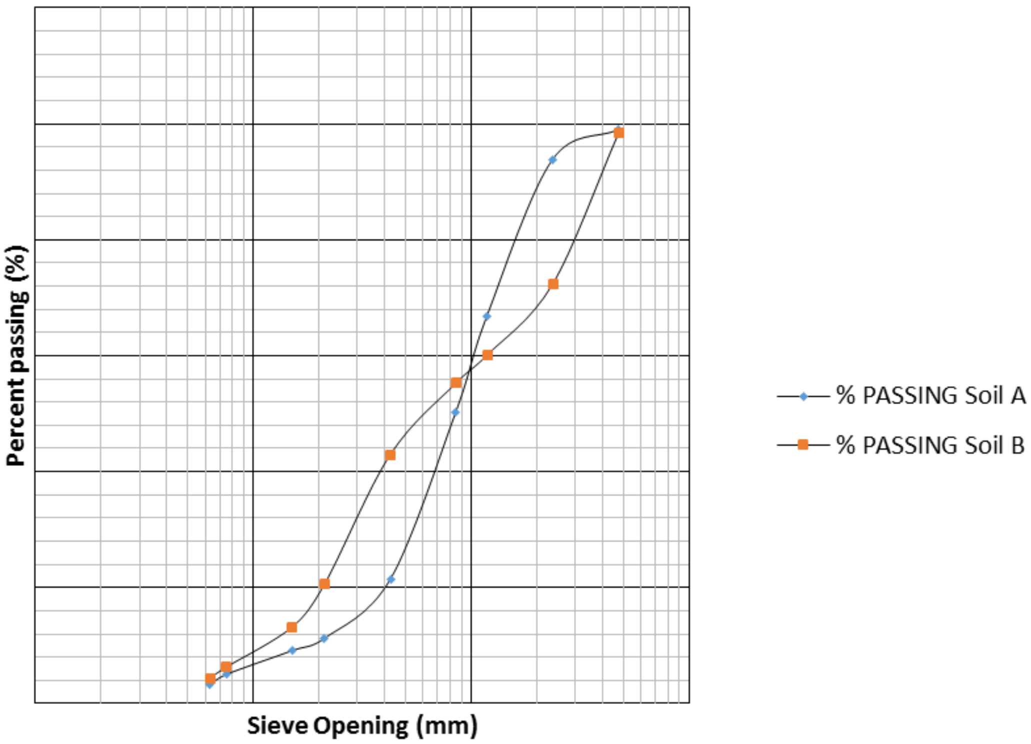

Figure 1: Grading Curve of Termite Mound and Sand

Results and Discussion

The results of the preliminary tests (grain size analysis, natural moisture contents and atterberg's limits) as well as compressive strength test are discussed below.

Preliminary Tests: The summary of the results of preliminary analysis on the samples is shown in the Figure 1. The initial moisture content test carried out indicated that water contents of 0.74% and 2.20% for soft sand and termite mound respectively. This indicates that the termite mound has a higher water retention capacity than soft sand. This could be ascribed to the void ratio. Termite mound had the largest void ratio compared to sand. This also showed that the soil samples contained appreciable amount of moisture, which is a function of the climatic condition, such as temperature and intensity of rainfall. The sieve analysis of dry samples of termite mound and sand used were carried out using the available sieve sizes ranging from 4.75mm to 0.063mm. The aim was to determine the grading of each of the soil type used and whether each sample was suitable for the intended purpose or not. The coefficient of uniformity of each soil type was calculated by reading D10 and D60 values from Figure 1. The fineness moduli of the soil materials used were calculated as 2.13 for soft sand and 2.09 for termite mound. These values indicate fine aggregate of medium grading. The values of D10 and D60 respectively can be determined for each soil type in the calculation of its coefficient of uniformity (CU).

For Termite mound, $$C_U = \frac{D60}{D10} = \frac{0.9}{0.3} = 3$$

For Sand, $$C_U = \frac{D60}{D10} = \frac{1.18}{0.27} = 4.37$$

The coefficient of uniformity were obtained as being approximately equal to 4.4 and 3 for soft sand and termite mound soil samples, respectively. The values show that the soil samples are uniformly graded and are suitable for making good mortar.

The chemical analysis of termite mound was found to contain up to 70.78 % of silica oxide, 15.78% of aluminium oxide and 5.69% of iron oxide. The mean compressive strength of termite mound blended cement mortar and the effect of curing age and percentage replacement of cement with termite mound and lime is presented in Figures 1 to 10. From the results it can be observed that the cube exhibited higher compressive strength when cured in water that is at 0% replacement for both mix ratios 1:4 and 1:6 the compressive strength generally decreased with curing age and also decreased with percentage replacement of cement with lime and termite mound. At various level of termite mound content (0%, 10%, 20%, 30%, 40% and 50%.

The compressive attainment at 7 days ranges from 3.60 N/mm2 to 18.00 N/mm2 for the specimen cured in water while the compressive strength of those cured in acids at 7 days ranges from 0.60 N/mm2 to 6.40 N/mm2. For the blended mixes. For 0% replacement the compressive strength were 9.40 N/mm2, 10.80 N/mm2, 13.40 N/mm2, 16.40 N/mm2 and 18.00 N/mm2 at 7, 14, 21, 28 and 56 days, respectively. The compressive strength for the specimen cured in H2SO4 were 4.40 N/mm2, 4.20 N/mm2, 4.08 N/mm2, 4.00 N/mm2 and 3.88 N/mm2. While those that cured in HNO3 were 5.80 N/mm2, 5.40 N/mm2, 5.28 N/mm2, 5.16 N/mm2 and 4.80 N/mm2. The compressive strength for the specimen that cured in H2SO4 continuously decreases from 2.16 N/mm2 at 14 days to 2.12 N/mm2 at 28 days at 10% replacement. This is lower than that of HNO3 which decreases from 2.80 N/mm2 at 14 days to 2.04 N/mm2 at 28 days. At 56 days the compressive strength of HNO3 was found to be higher than that of H2SO4. Therefore, for all the percentage replacements, HNO3 has much destructive ability than H2SO4 although the two acidic media are not concrete or mortar friendly.

The effect of curing age at different percentage replacement of mortar sample and their curing in the 1% and 3% concentration of H2SO4 and HNO3 were also examined as well as the relationship between strength, curing ages and the effect of curing medium on the compressive strength of the mortar. It was observed that the mortar sample cured in 1% of the acids tends to have lesser effect on the compressive strength as compared to samples cured in 3% of the acid. This shows that the higher the concentration of the acid in the curing medium the lesser the compressive strength of the mortar. When cured in water the compressive strength of the mortar increases as the curing age increases, but in the acidic medium the strength of the mortar sample decreases as the curing age increases.

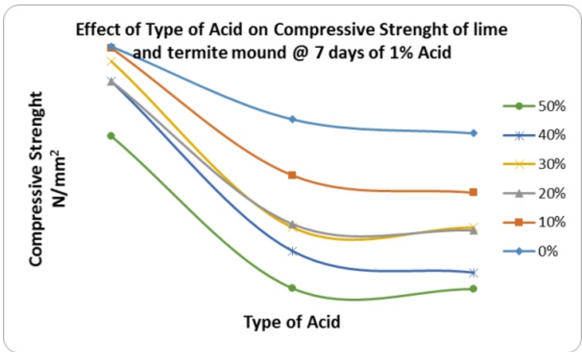

Figure 1: Effect of Acid on Compressive strength at 7 days at 1%

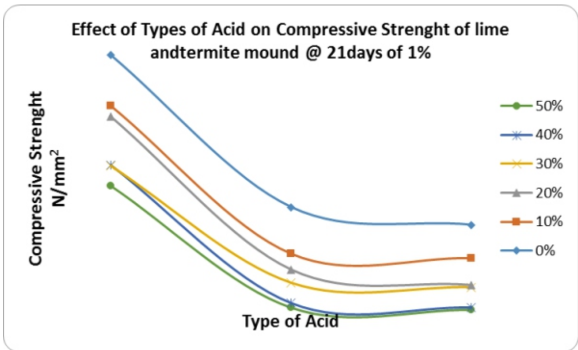

Figure 3: Effect of Acid on Compressive strength at 21 days at 1%

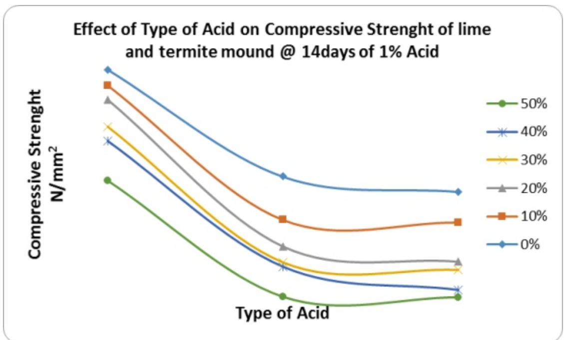

Figure 1: Effect of Acid on Compressive strength at 14 days at 1%

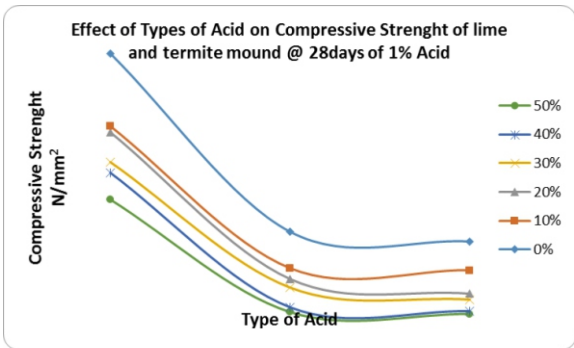

Figure 4: Effect of Acid on Compressive strength at 28 days at 1%

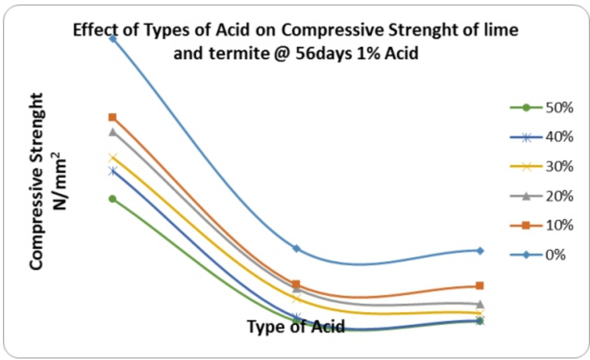

Figure 5: Effect of Acid on Compressive strength at 56 days at 1%

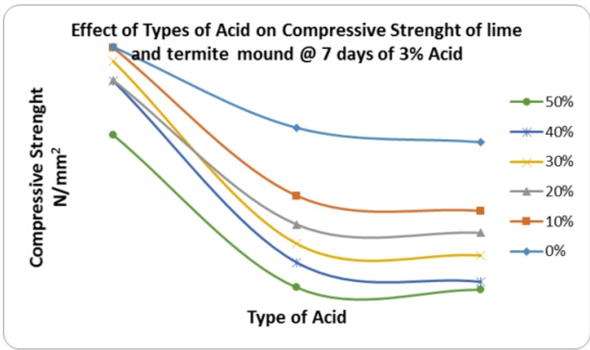

Figure 6: Effect of Acid on Compressive strength at 7 days at 3%

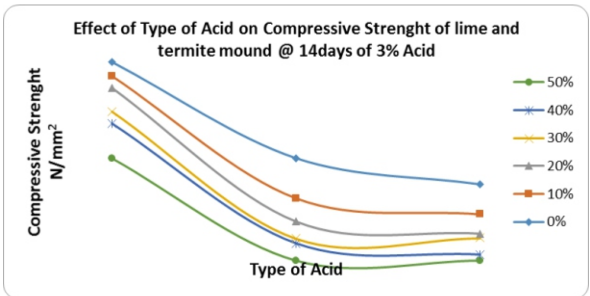

Figure 7: Effect of Acid on Compressive strength at 14 days at 3%

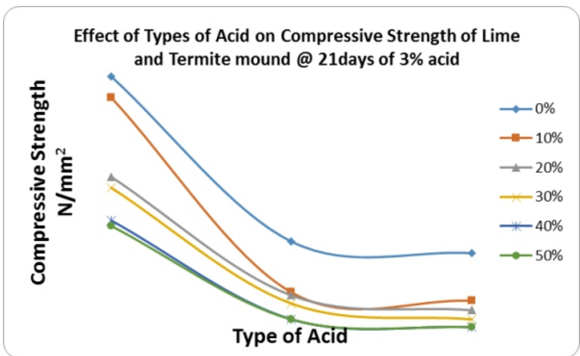

Figure 8: Effect of Acid on Compressive strength at 21 days at 3%

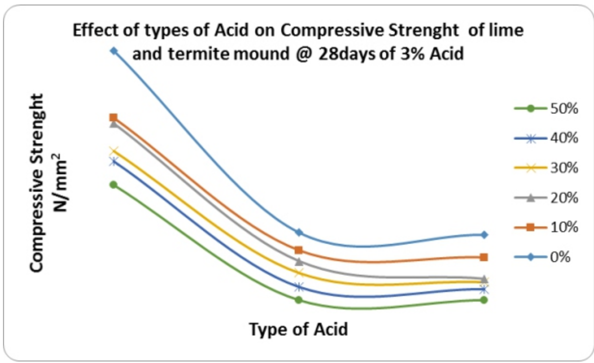

Figure 9: Effect of Acid on Compressive strength at 28 days at 3%

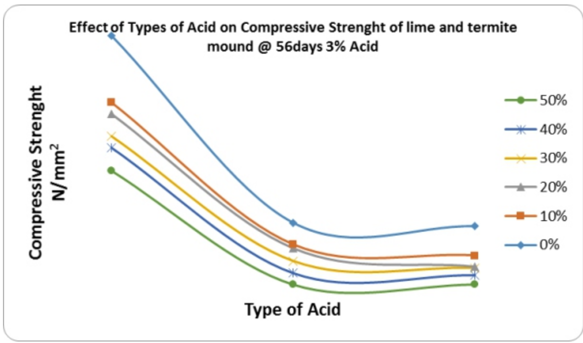

Figure 10: Effect of Acid on Compressive strength at 56 days at 3%

Conclusions

The following conclusions can be made from this study that the compressive strength of the mortar increases with age but decreased with percentage replacement of cement with termite mound and lime when cured in water. For the specimens that was cured in acid, the higher the concentration of the acid, the lower the compressive strength of the mortar sample. The compressive strength of the sample cured in tetraoxosulphate vi acid (H2SO4) is higher than of trioxonitrate v acid (HNO3).

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