Humidity Intrusion Effects on Properties of Autoclaved Aerated Concrete

Sasan Somi

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Prof. Dr. Elvan Yılmaz
Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Civil Engineering.

Assist. Prof. Dr. Mürüde Çelikağ
Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Civil Engineering.

Assoc. Prof. Dr. Özgür Eren
Supervisor

Examining Committee

1. Assoc. Prof. Dr. Özgür Eren
2. Assist. Prof. Dr. Abdullah Keyvani
3. Assist. Prof. Dr. Alireza Rezaei
4. Assist. Prof. Dr. Serhan Şensöy
5. Assist. Prof. Dr. Giray Özay

ABSTRACT

Autoclaved Aerated concrete (AAC) has many benefits for structures such as heat insulation, sound insulation, fire and mold resistance, reduced dead weight and many more. AAC products include blocks, wall panels, floor and roof panels, and lintels. Besides insulating capability, one of AAC's advantages in construction is its quick and easy installation since the material can be routed, sanded and cut to size on site using standard carbon steel band saws, hand saws and drills.

Although ACC is being produced for many years, there are still some points that need to be clarified. One of these points is humidity intrusion effects on AAC members in areas with high relative humidity levels of Mediterranean climates which are important in durability and insulation properties of AAC. Therefore some tests on mechanical and physical properties of ACC concrete was carried out. These were planned to be compressive strength and flexural strength tests. Apart from these tests thermal and sound insulation values under different level of humidity were measured for different combinations of ACC blocks. These combinations were based on varying thickness and plasters on the surfaces. From the findings of this study, physical and mechanical autoclaved aerated concrete were evaluated in three different humidity levels to compare the effects of humidity on properties of AAC.

Keywords: AAC, Concrete, Humidity, Insulation

ÖZ

Gaz betonun (GB) yapılarda kullanılmasının pek çok önemli avantajları vardır. Bunların bazılar ısı izolasyonu, ses izolasyonu, ateşe ve yangına dayanıklılığı ve binayı hafifletmesi sayılabilir.

Gaz beton ile üretilen malzemeler ise blok, duvar panelleri, zemin ve tavan panelleri ve kapı percere başlıkları olarak mevcuttur. Yalıtım yapmasının avantajı yanında gaz betonun çok hızlı bir şekilde örülmesi ve monte edilmesi, normal bir testere ile kolayca kesilebilmesi veya matkap ile delinebilmesi de çok önemli avantajlarıdır.

Gaz beton çok uzun bir süredir üretilmesi ve kullanılmasına rağmen hala da merak edilen ve araştırılması gereken konular vardır. Bunlardan bir tanesi de gaz betonun farklı nemli ortamlardaki davranışıdır. Özellikle Akdeniz iklimindeki yüksek nem oranının bu malzeme nin fiziksel ve mekanik özelliklerine olan etkisi çok fazladır.

Bu çalışmada esas olarak farklı nemli ortamlarda bulunan gaz betonun basınç dayanımı, eğilme dayanımı, ısı ve ses iletkenlik özellikleri ölçülmüş ve bunlar arasındaki değişiklikler ortaya konulmaya çalışılmıştır.

Anahtar kelimeler: gaz beton, beton, nem, izolasyon.

To My Family

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I owe quit a lot to my family who allowed me to travel all the way from Iran to Cyprus and supported me all throughout my studies. I would like to dedicate this study to them as an indication of their significance in this study as well as in my life.

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LIST OF SYMBOLS

AAC	Autoclaved Aerated Concrete
ASTM	American Society for Testing and Materials
BS	British standards
DIN	Deutsches Institute Fur Normung
dB	Decibels
LWC	Lightweight concrete
NAAC	None Autoclaved Aerated Concrete
TS	Turkish standards
TS=EN	Turkish European Standards

Chapter 1

INTRODUCTION

Autoclaved Aerated Concrete can also be named as AAC and is an important construction material for architects, engineers and builders. Also it is an appropriate material with high energy efficiency, fire safety, and cost effectiveness.

1.1 History of AAC

First inventor of AAC was a Swedish Engineer who created AAC in 1922. Manufacturing of concrete using steam pressure goes back to 1880, when AAC was brought to Germany, Manufacturers were facing problems to find a proper method for cutting this material, and German engineers solved this problem by introducing a new method known as Wire Cutting which increased the rate of production for AAC. After creation of that cutting method, AAC became an adequate material with respect to Germany's firm energy codes. AAC had no standard code of practice and this delayed introduction of it into USA market. Second production of AAC was done by Ytong in 1997 in Germany [1].

1.2 Objectives of Study

Although AAC is being produced for many years, there are still some points that need to be clarified. Humidity intrusion effects on AAC in the areas with high level of relative humidity (such as Mediterranean climates) are important in durability and insulation properties of AAC. Different tests on autoclaved aerated concrete were carried out in three different humidity levels to compare the effect of humidity on mechanical and physical properties of AAC.

1.3 Works Done

In order to achieve the aims and objectives explained in section 1.2 the following works were done:

1. A literature survey on autoclaved aerated concrete was carried out
2. Standards such as TS, BS, ASTM, DIN were used to make the experiments for this investigation.
3. Cutting process was done for preparing specimens in different dimensions according to the standards for testing procedures.
4. Drying process was carried out to reach lowest level of humidity for samples which is 6% according to the TS standard.
5. Experiments in order to investigate the physical and mechanical properties of autoclaved aerated concrete were carried out. These tests were sound insulation test, thermal conductivity test, compressive strength and flexural strength tests. Fire resistance and water absorption tests were also carried out to determine other performance of AAC.
6. Analyzing and discussing of results were carried out after finishing all the experiments.

1.4 Achievements

Achievements in this study are as following:

1. Physical properties such as thermal conductivity and sound insulation capacity were evaluated for 3 different temperatures under different humidity levels for two types of AAC walls (with coating and without coating).
2. Humidity levels inside the chamber were provided by using different methods.
3. Water absorption capacity of AAC block was measured.
4. Fire resistance test was carried out for determining the ability of material to withstand agianst fire. This test was carried out for six different temperatures increasing from 100°C to 1000°C .
5. Mechanical properties of AAC were evaluated as compressive strength and flexural strength tests. Compressive strength test was carried out for 3 different levels of humidity such as fully saturated, 50% relative humidity and oven dried samples with 6% relative humidity. Performance against compressive strength after fire was evaluated.

1.5 Guide to Thesis

Chapter 2 deals with historical prospective of AAC which briefly describes previous studies and works carried out, applications of AAC, advantages of AAC, manufacturing process of AAC, and raw materials used to manufacture AAC. Chapter 3 will explain experimental program carried out in this study and describes the procedure of different tests on AAC. Chapter 4 concentrates on results and discussion of obtained data from tests. Chapter 5 summarizes works done in this study, conclusion and recommendations for future study.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

2.1.1 Lightweight Concrete

Lightweight concrete is 87% to 23% lighter than normal weight concrete. Romans were the first inventor of lightweight concrete (LWC) in the second century. Most important properties of LWC are low density and low thermal conductivity. It also allows constructors to reduce the dead weight of a building. Lightweight concrete became very popular in USA, United Kingdom and Sweden also. Building of Pantheon which was made from Lightweight concrete is still standing extremely in Rome until now for about 18 Centuries. (See Figure 2.1)[2].

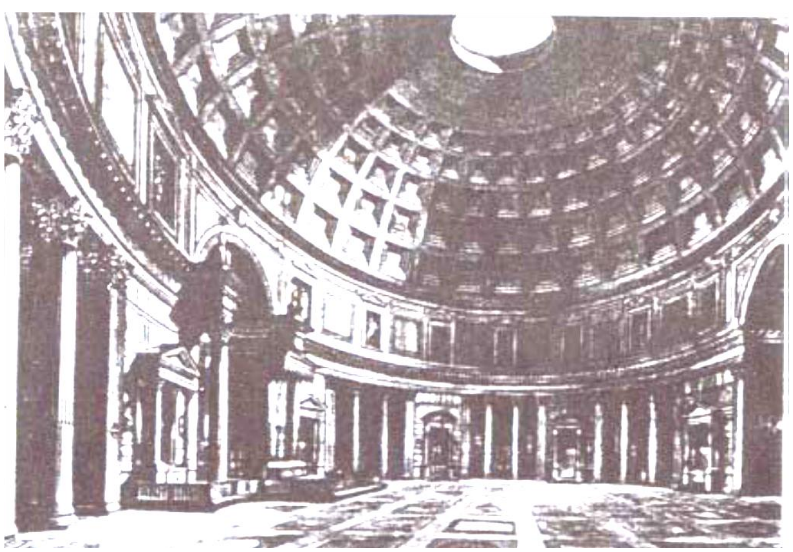

Figure 2.1: The Pantheon [2]

2.1.2 Types of Lightweight Concrete

Lightweight concrete can be produced in three categories:

1. No-fines concrete
2. Lightweight aggregate concrete
3. Aerated concrete

2.1.2.1 No fines Concrete

No fines concrete is lightweight concrete which contains cement and fine aggregate. Voids have homogeneously dispersed and formed during its production. Major property of lightweight concrete with no fines is keeping its outsized voids and avoiding formation of cement layer during placing on wall.

Concrete with no fines can be useful on each type of walls including load bearing and non-load bearing. If the aim is reaching a better strength for lightweight concrete, increasing cement content will be a useful solution [3].

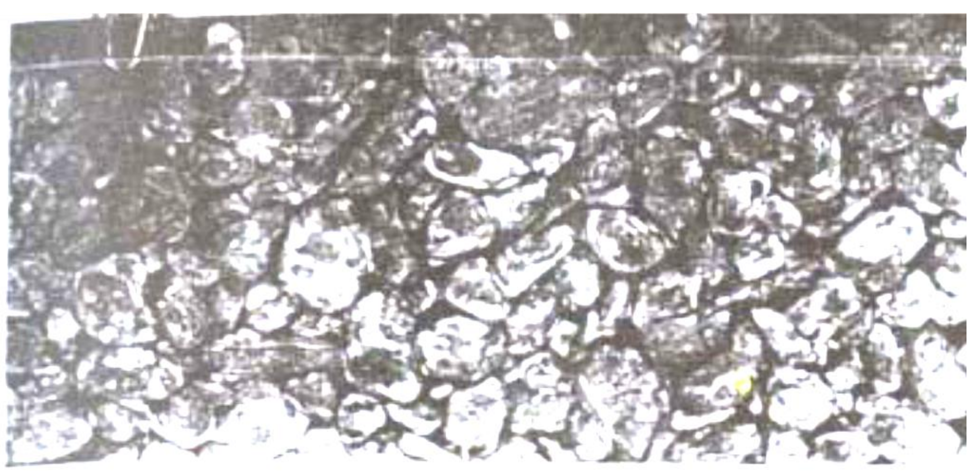

Figure 2.2: No-fines Concrete [2]

2.1.2.2 Lightweight Aggregate Concrete

For manufacturing this type of concrete lightweight aggregates with porous structure are useful. Two types of porous aggregate are adaptable for lightweight aggregate concrete which are lightweight aggregates with natural source such as pumice and also aggregates with volcanic source such as blast furnace slag. There are two main types of lightweight aggregate concrete that can be defined according to their compaction level; partially compacted lightweight aggregate concrete and fully compacted lightweight aggregate concrete.

Partially compacted light weight aggregate concrete is useful for precast concrete blocks. Fully compacted type is suitable for using with reinforcement because of providing stronger bond between reinforcement and concrete. This type of lightweight aggregate concrete is appropriate for structural uses. (See Figure 2.4 as an example of lightweight concrete) [2].

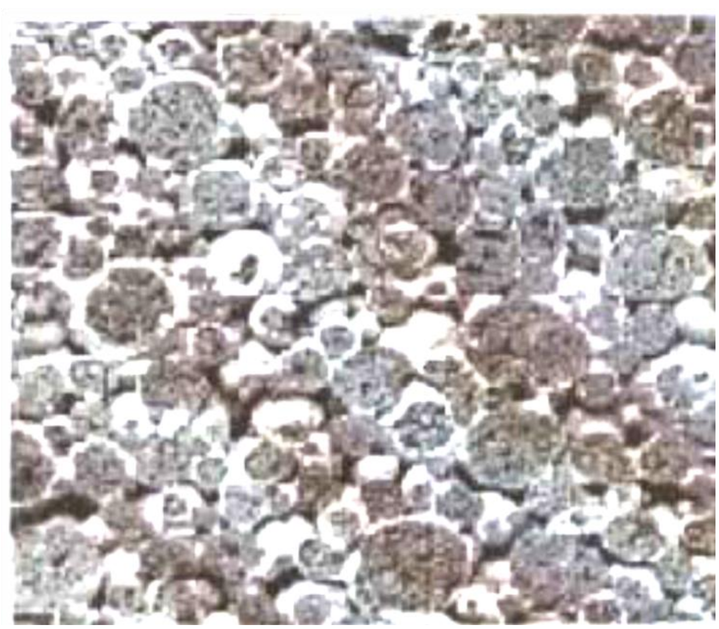

Figure 2.3: Lightweight Aggregate Concrete [2]

2.1.2.3 Aerated Concrete

This type of lightweight concrete has no coarse aggregates in its mixture, and it can be mentioned that aerated lightweight concrete is the concrete mortar which is aerated with gas injection and also can be aerated by using air entraining agent. Aerating concrete by using air entraining agents is more practical in production of LWC. Fine aggregates that can be used to produce aerated concrete are known to be silica sand, quartzite sand, lime and fly ash [3].Considering methods of curing, aerated concrete can be categorized into two main groups which are autoclaved aerated concrete and non-autoclaved aerated concrete. Curing is an important factor affecting mechanical and physical properties of concretes in different categories. According to different reports, AAC can reach higher strength values with less drying shrinkage when it is compared to non-autoclaved aerated concrete (NAAC). Therefore it can be concluded that autoclaving process has beneficial effects on strength development and also on shrinkage of aerated concrete [4].

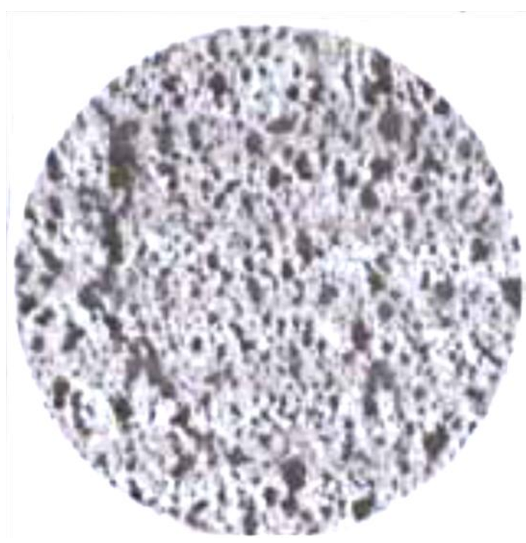

Figure 2.4: Aerated Concrete [2]

Table 2.1: Grading and types for aggregates which are appropriate for different types of lightweight concrete [2].

Type Of Lightweight Concrete	**Type Of Aggregate**	**Grading of Aggregate (Range of Particle Size)**
No-fines concrete	Natural Aggregate Blast-furnace slag Clinker	Nominal single-sized material between 20mm and 10mm BS sieve
Partially compacted lightweight aggregate concrete	Clinker Foamed slag Expanded clay, shale, slate, vermiculite and perlite Sintered pulverized-fuel ash and pumice	May be of smaller nominal single sizes of combined coarse and fine (5mm and fines) material to produce a continues but harsh grading to make a porous concrete
Structural lightweight aggregate concrete	Foamed slag Expanded clay, shale or slate and sintered pulverized fuel ash	Continues grading from either 20mm or 14mm down to dust, with an increased fines content (5mm and fines) to produce a workable and dense concrete
Aerated concrete	Natural fine aggregate Fine lightweight aggregate Raw pulverized-fuel ash Ground slag and burnt shales	The aggregate are generally ground down to finer powder, passing a 75 µm BS sieves, but sometimes fine aggregate (5mm and fines) is also incorporated

2.2 Autoclaved Aerated Concrete

This study is based on properties of autoclaved aerated concrete and evaluating humidity intrusion effects on properties of AAC. This section contains information about manufacturing process, raw materials, advantages and also applications of autoclaved aerated concrete.

2.2.1 Manufacturing Process

Manufacturing process of AAC has many similarities to producing precast concrete.

This process contains 5 main steps which are as following:

1) Mixing of raw materials.

2) Addition of expansion agent.

3) Pre curing, cutting.

4) Curing process with autoclave.

5) Packing and transporting.

2.2.1.1 Mixing of Raw Materials

In this part of manufacturing process, fine aggregates like silica sand or quartz sand and lime are mixed with cement. Then water will be added to this mix and hydration starts with cement forming bond between fine aggregates and cement paste. All these processes take place in a huge container [1].

2.2.1.2 Addition of Expansion Agent

After mixing process, expansion agent is added to the mix for increasing its volume and this increase can be from 2 to 5 times more than original volume of the paste. Expansion agent which is used for this process is aluminum powder; this material reacts with calcium hydroxide which is the product of reaction between cement and water. This reaction between aluminum powder and calcium hydroxide causes forming of microscopic air bubbles which results in increasing of pastes volume. These microscopic air bubbles will increase the insulation capacity of AAC.

This reaction is shown in following equation [1]:

$$2Al + 3Ca(OH)_2 + 6H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + 3H_2$$

Aluminum Powder + Hydrated Lime → Tricalcium Hydrate + Hydrogen

2.2.1.3 Pre curing and Cutting

Pre curing process starts after concrete mix is poured into metal moulds with dimensions of 6000 mm × 1200 mm × 600 mm. In these moulds, concrete will be pre cured after it is poured into mould to reach its shape and after this pre curing process cutting will take place. Cutting will be done with wire cutter to avoid deformation of concrete during process [1].

Aerated concrete blocks are available in different dimensions and various thicknesses. Dimensions for these blocks which are commonly used are:

600 mm×250mm×100mm

600mm×250mm×150mm

600mm×250mm×200mm

2.2.1.4 Curing Process by Autoclave

Autoclave is defined as a strong, pressurized and steam-heated vessel. Concrete mix that is categorized as autoclaved has its ultimate mechanical properties conditions. In order to reach the ultimate mechanical characteristics for AAC, Domingo (2008) states that;

“quartz sand should react with calcium hydroxide that evolves to calcium silica hydrate causing material to reach its fixed mechanical and physical properties” [1]. Curing with autoclaving method requires three main factors which are moisture, temperature and pressure. These three factors should be applied on material all at the same time.

Temperature inside autoclave should be 190° C and essential pressure should be about 10 to 12 atmospheres. Moisture will be controlled by autoclave and this process should be continued up to 12 hours to provide proper condition for hydration [1].

2.2.1.5 Packing and Transporting

After completion of mentioned processes, autoclaved aerated concrete is ready for packing and transportation, but the important factor that shall be carefully considered for this process is that; material should be cooled down for packing and transporting [1].

Figure 2.5: Transportation of the AAC to jobsite [1]

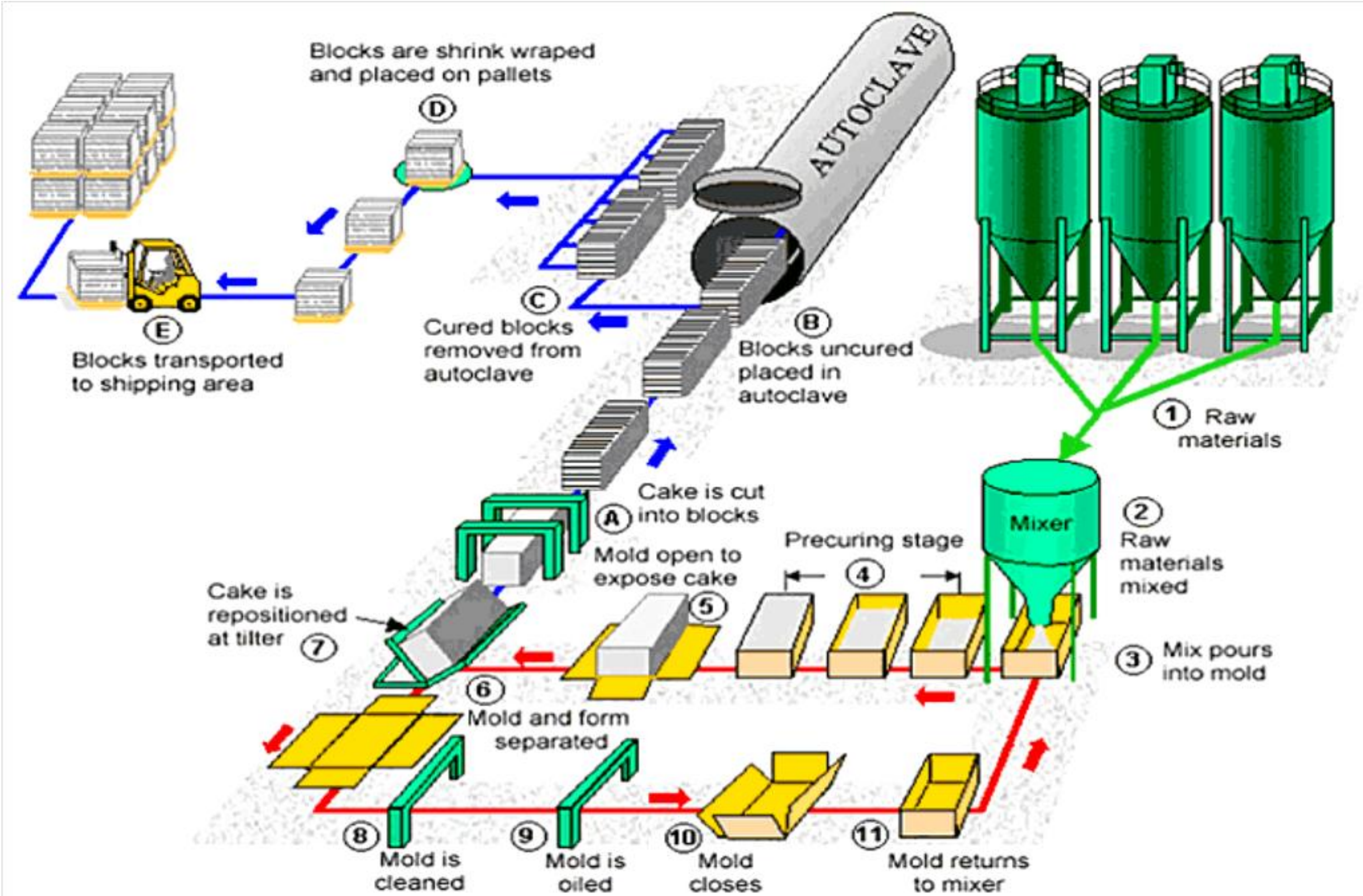

Figure 2.6: Manufacturing Process of AAC Masonry Units [6]

2.2.2 Raw Materials

Raw materials which are appropriate for autoclaved aerated concrete are fine grading materials. Silica or quartz sand, lime, cement and aluminum powder are main raw materials for producing AAC. Silica sand's percentage is higher than the other aggregates in aerated concrete mix. Both silica and quartz sand are mineral based aggregates which can be obtained from broken rocks or granites. At the same time fly ash, slag, or mine tailings can be used as aggregates in combination with silica [8].

In order to achieve porous structure of autoclaved aerated concrete and reduce its weight for increasing insulation capacity, air entraining agent must be used. Aluminum powder is the main choice for air entrainment of autoclaved aerated concrete. Aluminum powder is a combustible powder that can be obtained by grinding aluminum into fine grains of material. Amount of aluminum powder depends on density of concrete but normally it should be used at rate of 0.05 % to 0.08% by volume of paste. Appropriate cement for autoclaved aerated concrete is Ordinary Portland Cement (Type-1) which is used for production of conventional concrete [9].

2.2.3 Advantages of using Autoclaved Aerated Concrete

AAC has many advantages in building construction because of its lightweight and porous structure which allows this material to have excellent insulation properties. Some main properties of autoclaved aerated concrete are as following:

1. Structural capability
2. Sound insulation
3. Thermal insulation
4. Minimizes supplementary material utilization and waste

5. Precise dimension

6. High construction speed

2.2.3.1 Structural Capability

Concerning lightweight of autoclaved aerated concrete, low compressive strength is predictable, but experiments show that AAC's compressive strength is acceptable for using as load bearing wall units for residences up to three storey.

Compressive strength of AAC varies with density of concrete which is 2.5 N/mm^2 for average of 450×10^9 kg/mm^3 density and 5 N/mm^2 for average of 650 $\times10^9$ kg/mm^3 density. Compressive strength for average density of 700×10^9 kg/mm^3 is reported to be 7.5 N/mm^2 [10].

2.2.3.2 Sound Insulation

Autoclaved aerated concrete has excellent noise reducing ability and causes reduction in sound transmission. Porous structure of AAC contains millions of air bubbles which restrict sound penetration inside the wall and because of this property autoclaved aerated concrete has better sound insulation capacity than normal concrete [10].

2.2.3.3 Thermal Insulation

Thermal insulation of autoclaved aerated concrete allows energy savings up to 35% more than other masonry materials. AAC is recognized to have good thermal insulation property because of its R value rating (1.43 for 6% humidity inside the material) and air bubbles inside the material which plays as a key role in making it satisfactory for thermal insulation [10].

2.2.3.4 Supplementary Material Utilizations

Structure of autoclaved aerated concrete contains 70% to 75% air voids, which allow saving in raw materials consumption during production. On the other hand for manufacturing AAC, recycled material can also be used which reduces cost of production [10].

2.2.3.5 Precise Dimension

Since autoclaved aerated concrete's cutting procedure is carried out with wire cutting method, it minimizes variations in size and causes walls to have smooth surface that every coating material could be applied easily [10].

2.2.3.6 High Construction Speed

Constructing walls with autoclaved aerated concrete needs less time than other concrete masonry blocks, AAC walls can be erected easily by using small number of labor. This will reduce the cost of building compared to other types of wall construction materials.

It is reported that an experienced crew of eight can set 731.52 mm of wall space and 1097.28 mm of floor space with one small crane per day [10].

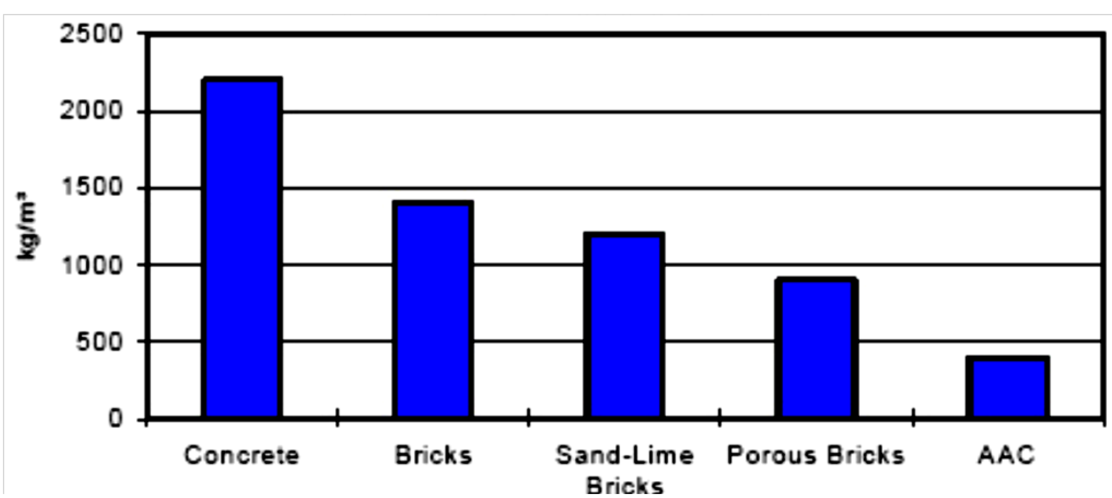

Figure 2.7: Raw materials consumption of different building materials [7]

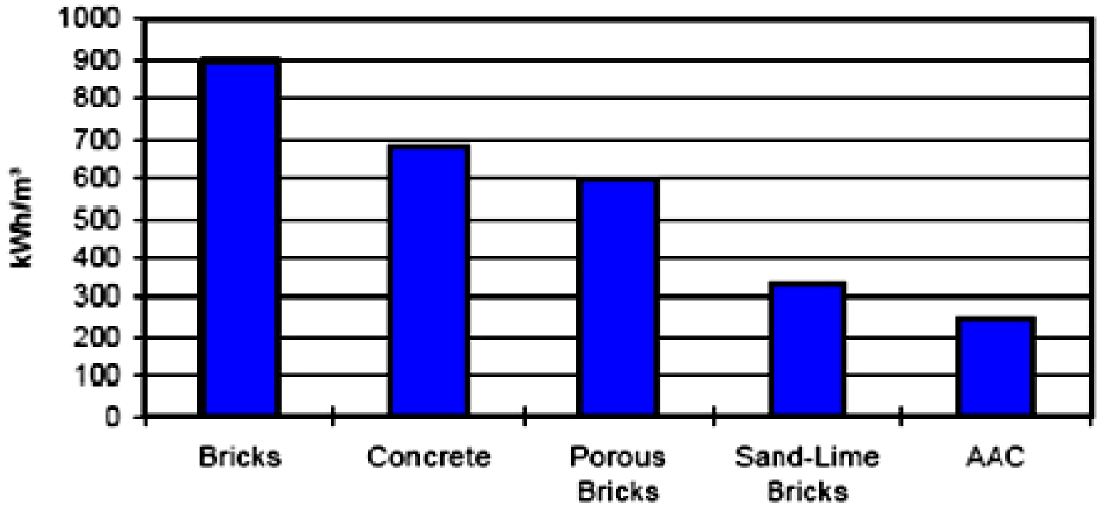

Figure 2.8: Energy consumption of different building materials [7]

2.2.4 Application of AAC

Autoclaved aerated concrete blocks can be useful in various building types such as commercial, residential and educational. These blocks are applicable in warehouses and buildings with industrial aim, bearing in mind their high insulation capacities, less construction time, cost effectiveness and also their light weight which reduces dead load of building, considerably makes AAC an adequate material to use.

AAC blocks can be appropriate in different parts of building; it can be used in both non-load bearing and load bearing walls. Autoclaved aerated concrete blocks can be applicable on floor panels or as a cladding application for roof systems [11].

Figure 2.9: Construction of masonry wall with AAC blocks [11]

Considering applications and advantages of AAC in construction objectives of this study were based on determining humidity intrusion effects on properties of AAC to evaluate its performance in areas with high relative humidity which is important in durability and insulation properties of AAC. For this matter Experiments were carried out in order to investigate physical and mechanical properties of AAC. Chapter 3 explains experimental program carried out in this study and describes the procedure of different tests on AAC.

Chapter 3

EXPERIMENTAL PROCEDURE

Experiments were carried out in order to investigate physical and mechanical properties of autoclaved aerated concrete. These properties are compressive strength, flexural strength, fire resistance, sound acoustic, thermal conductivity and water absorption. This chapter includes brief descriptions about experimental procedure of tests which were carried out according to EN, ASTM and TS.

3.1 Compressive Strength Test

Compressive strength of AAC is an important parameter in construction and design. Compressive strength tests were carried out by applying axial load on AAC cubes. For this test AAC cubes were cut into desired dimensions by using cutting machine, to obtain sample with dimensions of 150×150×150 mm and 50×50×50 mm. This test was carried out on samples with three different humidity conditions of 6%, 50% and 100%. For each humidity condition, four 150 mm cubes and four 50 mm cubes were tested. Procedures of this test were based on TS-EN 679 standard [14].

AAC cubes were oven dried for three days in 60°C according to TS-pr EN 1353 [18], to reach 6% humidity condition. For 100% humidity condition AAC cubes were kept in water tank for three days to achieve this condition. For 50% humidity condition, samples were at first saturated brought back to 50% humidity condition based on trial weighing until required humidity.

Figure 3.1: Humidity adjustments of samples.

Figure 3.2: Specimens in oven for drying process.

3.1.1 Apparatus

compressive test machine used for determination of compression strength on samples of building materials, especially for efficient quality control on concrete cubes and cylinders as well as on all kind of bricks. Tests are prepared, performed, monitored and evaluated via software and also this testing machine can provide max axial load of 4000KN.

Figure 3.3: Compressive strength test machine.

3.2 Flexural Strength Test

For this purpose, concrete beams were loaded with 3 point loading method as described in Figure3.4. Flexural strength of specimens was calculated by using below formula (ASTM C78) [15].

$F_r = M_{cr}/w_{cr}$

M_{cr}= ultimate bending moment of crushed section [kg-mm]

w_{cr} = modulus of crushed section [mm^3]

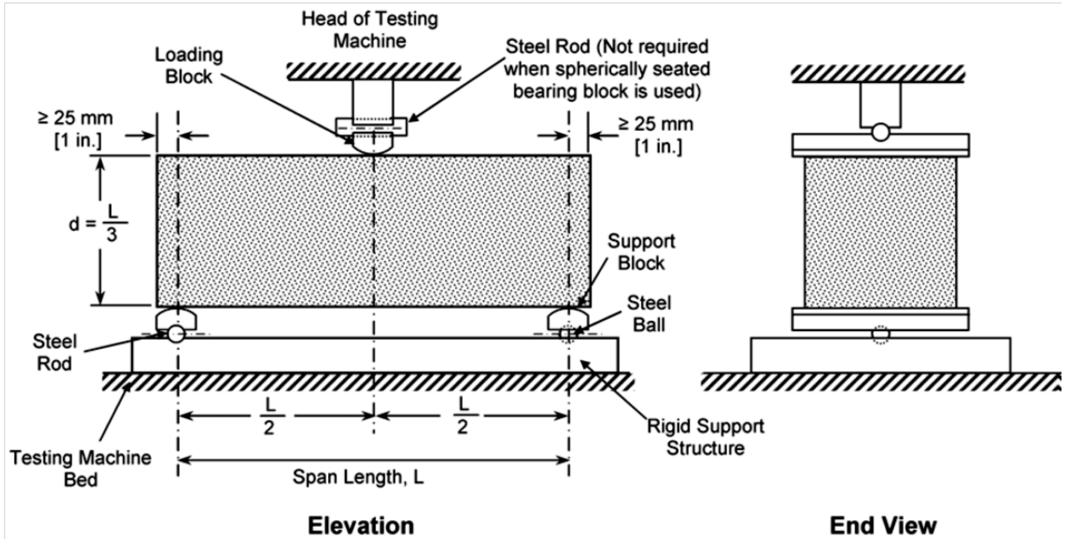

Figure 3.4: Schematic Drawing of Flexure Test.

3.2.1 Sample Preparation

Flexural strength specimens were cut into desired dimensions of 40×40×160 mm and four samples were used for flexural strength test. Samples were dried in oven for three days to reach 6% humidity condition according to TS-pr EN 1353 [18].

Figure 3.5: Flexural strength test apparatus.

3.3 Sound Acoustic Test

Sound acoustic tests were carried out for evaluating acoustic properties of AAC panels under three different humidity conditions. For these tests, special chamber made of galvanized steel plates was prepared with dimensions of 700×850×600 mm. Distance between the two steel panels of chamber was filled with lightweight material and gypsum mortar to increase its insulation capacity.

Figure 3.6: Outside view of the test chamber.

3.3.1 Test Equipment

Sound acoustic tests were carried out by the following procedures:

Sound level meter with accuracy of 0.1 dB was used to measure frequency of sound at both inside and outside of chamber. A humidity meter was used to measure the humidity level and temperature inside the chamber. Speakers were used to produce sound inside the chamber which was connected to a computer for sound production with homogenous frequency. Plastic funnel was used to reduce disturbing noises which causes faults in the measurements.

Figure 3.7: Setup of apparatus inside of the chamber.

.

3.3.2 Testing Procedure

Measuring sound levels inside the chamber was the first step of test and a digital camera with flashlight was used inside the chamber to record data from sound level meter. Ten different sound levels were set for computer to be applied in the chamber changing from 55.4 dB up to 87.5 dB. Sound levels were measured outside and inside of AAC wall to determine loss of sound transmission.

Sound acoustic tests were carried out in two important cases for targets of this thesis:

1) Three different humidity conditions were set for AAC walls. Different humidity conditions in the chamber were created by using a vapor producer.

2) Effect of coating on acoustic properties of AAC walls was studied. The coating used was gypsum plaster with a thickness of 10 mm.

Figure 3.8: Sound level measuring test process

3.4 Fire Resistance Test

Fire resistance test was done to find out effects of fire on the properties of AAC. Test was done on 50x50x50 mm cubes at six different temperatures. These temperatures were fixed to be 100°C, 300°C, 500°C, 700°C, 900°C and 1000°C, and were on the electrical muffle furnace. Three AAC samples were tested for each temperature.

AAC blocks were cut by using a cutting machine; all the blocks were dried at temperature of 60°C for the period of three days by using electrical oven. Each of the three samples selected for testing should be faced to desired temperature inside the oven for 30 minutes. Each sample was weighted before and after testing for determining effect of fire on the weight loss of AAC blocks. After fire resistance test, compressive strength of the samples was determined to detect effect of fire on strength properties of AAC blocks [17].

Figure 3.9: Fire resistance test apparatus

3.5 Thermal Conductivity

Thermal conductivity tests were carried out for evaluating thermal insulation properties of AAC panels under three different humidity conditions. For this test special chamber made of galvanized steel plates was set with dimensions of 700×850×600 mm. Distance between two steel panels of chamber was filled with lightweight material and gypsum mortar to increase its insulation against sound and also to avoid sound transmission from door of chamber polyurethane foam injected inside the door panel.

3.5.1 Test Equipment

Electrical fire box was used for heating the chamber. Temperature inside the chamber was adjusted by using a thermostat. Four thermometers were used for monitoring temperatures inside and outside surfaces of AAC wall. Humidity meter was used to measure humidity level and temperature inside the chamber.

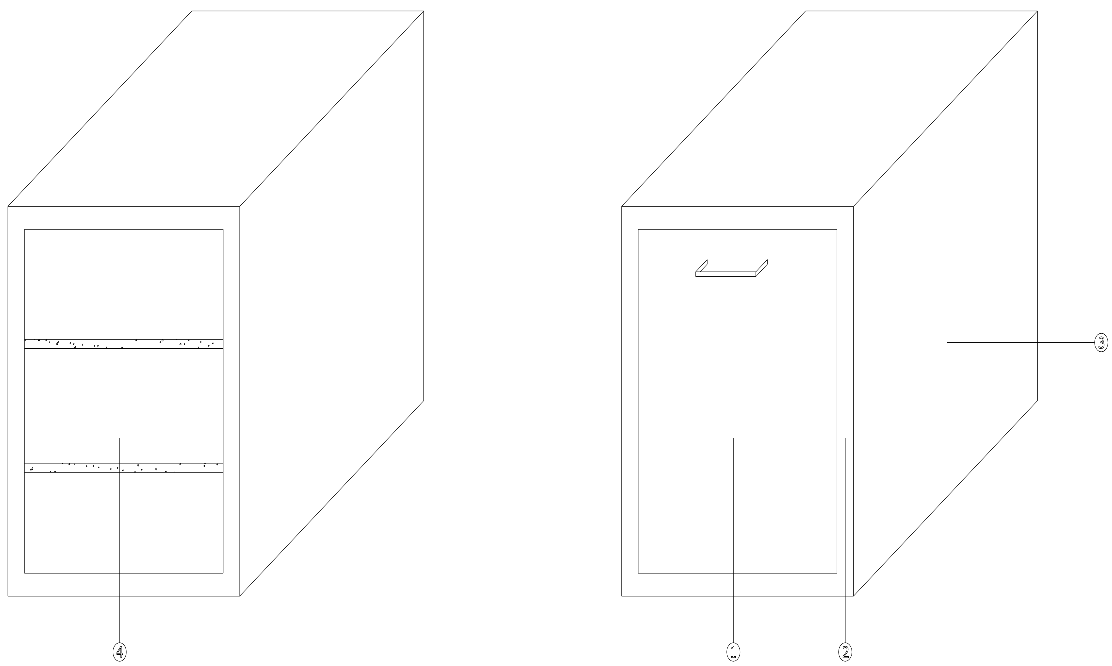

Figure 3.10: Schematic view of the test chamber.

1. Front side of chamber with door

2. Light concrete with gypsum mortar

3. Galvanized plate.

4. AAC wall

Figure 3.11: Heat production inside the chamber with electrical fire source.

3.5.2 Testing Procedure

Thermal conductivity tests were carried out at three different conditions:

1) Three different humidity conditions.

2) Gypsum coating was applied on the both faces of the AAC panel with a thickness of 10 mm.

3) AAC walls tested at three different temperature levels under steady state conditions. Samples were kept at specified temperatures for 90 minutes.

Tests were carried out at 40°C, 60°C, 70°C temperatures and three different humidity conditions of 55%, 70% and100%.

Figure 3.12: Thermal conductivity test setup

3.6 Determination of Coefficient of Thermal Conductivity of AAC Walls by Using Hot-Box Device

Hot-Box device was used for determining coefficient of thermal conductivity of AAC walls. Procedures of this test were performed according to TS EN ISO 8990 [16].Hot-Box contains two well insulated chambers as cold chamber and hot chamber that were conditioned by heating and cooling equipment to attain desired temperatures on each side of the wall. Both cold and hot chambers were cycled among different temperatures. These temperature cycles were programmed to simulate outdoor climatic conditions. Temperatures were determined by thermo-couples with a 0.1°C sensitivity. There were 9 thermo-couples existing on each chamber for measuring surface temperature of wall sample and 3 thermo-couples were available on each chamber for measuring temperature of chambers. Dimension of AAC wall which used for thermal conductivity test was 1200×1200 mm. All data (surface and ambient temperatures) were transferred to a PC and coefficient of thermal conductivity was calculated.

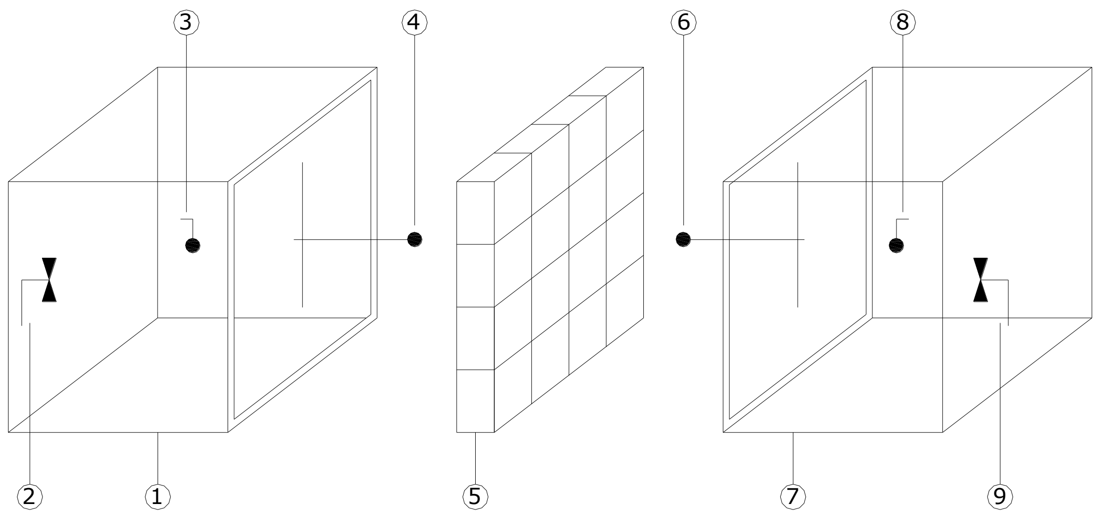

Figure 3.13: Schematic appearance of Hot-Box test mechanism.

1. Cold chamber

2. Freezer fan

3. Thermo couples (3unit) to measure the ambient temperature of cold chamber

4. Thermo couples (9unit) to measure the surface temperature (cold) of wall sample

5. Wall specimen (1200 mm× 1200mm)

6. Thermo couples (9 units) to measure the surface temperature (hot) of wall sample

7. Hot chamber

8. Thermo couples (3 units) to measure the ambient temperature of hot chamber

9. Heater fan

3.7 Water Absorption Test

Water absorption capacity was measured to determine amount of water which can be absorbed by AAC blocks from environment. For this test AAC blocks with dimensions of 150×150×150 mm and 50×50×50 mm were used. These blocks with desired dimensions were prepared by using a cutting machine. Samples were oven dried for three days at 60°C. After three days samples were weighted every one hour until no changes were observed in their weight. When samples dried completely, they were put into water tank for three days to make them fully saturated and at the end of three days samples were weighted again. Water absorption capacity was calculated by the following equation:

$$\% \text{ Water absorption} = [(\text{Wet weight} - \text{Dry weight}) / \text{Dry weight}] \times 100$$

Chapter 4

RESULTS AND DISCUSSION

4.1 Sound Insulation Test

Sound insulation tests were carried out on AAC panels under three different humidity conditions to determine effects of humidity on acoustic properties of AAC. Measuring sound transition loss (TL) was the main purpose of sound insulation test. Although mass and stiffness are the most important factors affecting sound transmission losses of partitions and floors, humidity can also be a factor which can affect sound transmission. According to technical report CBD-239; "in a double layer assembly, such as gypsum wallboard on wood or metal framing, the depth of air spaces, the presence or absence of sound absorbing material, and the degree of mechanical coupling between layers critically affect sound transmission losses and the sound transmission class (STC)".

Sound levels inside the chamber were increased from 55.4 dB to 87.6 dB under 55% humidity condition inside the chamber. Results obtained for sound insulation test on AAC wall without coating shows; sound levels outside the chamber were reduced by 41.08% comparing to sound levels inside of it. In the same test conditions results obtained for AAC wall with gypsum coating in 55% humidity condition shows 48.88% sound transmission loss.

Table 4.1: Sound levels inside and outside the chamber at 55% humidity condition for AAC wall without coating

Inside-sound level (db)	**Outside-sound level (db)**
55.4	34.7
65.8	35.7
71.7	39.9
75.5	41.7
79.2	45.7
81.9	47.1
83.7	50.0
84.6	51.5
86.4	53.7
87.6	54.7

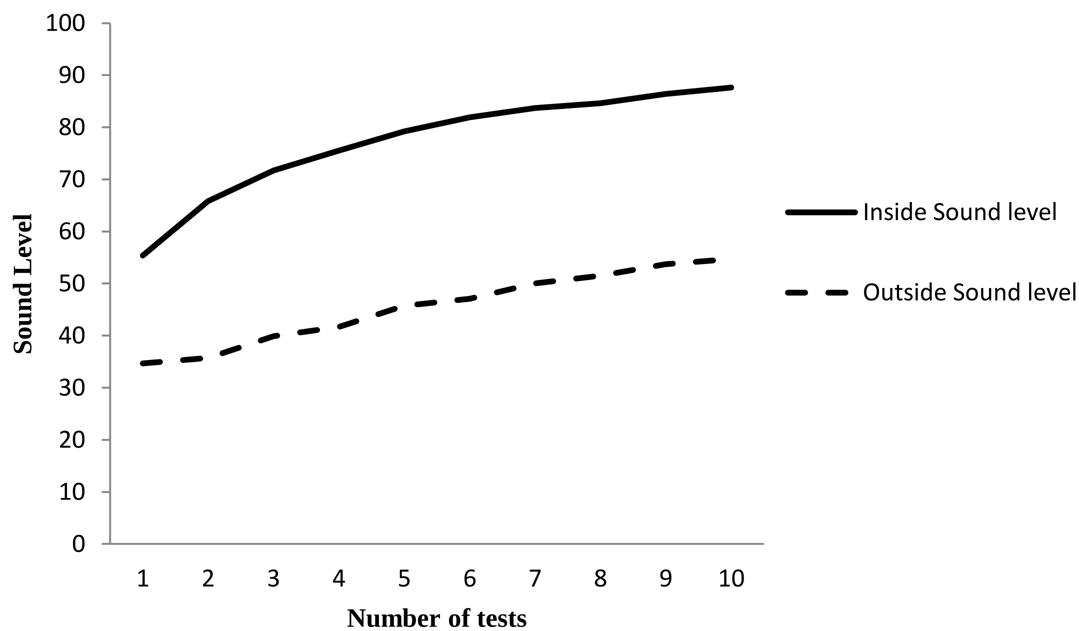

Figure 4.1: Sound transmission loss at 55% humidity condition for AAC wall without coating

Table 4.2: Sound levels inside and outside the chamber at 55% humidity condition for AAC wall with coating

Inside-sound level (db)	**Outside-sound level (db)**
55.4	34.0
65.8	34.8
71.7	35.8
75.5	37.7
79.2	39.2
81.9	40.5
83.7	41.5
84.6	42.1
86.4	43.3
87.6	45.6

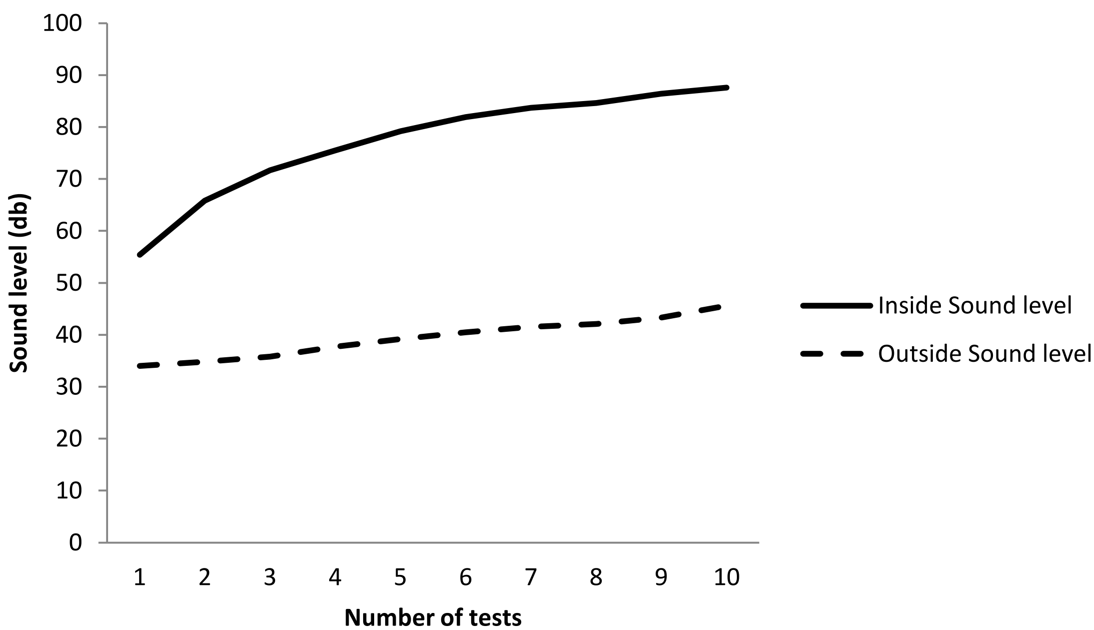

Figure 4.2: Sound level transmission loss at 55% humidity condition for AAC wall with coating

When inside humidity condition was about 75%, sound levels outside the chamber were measured for AAC wall without coating to determine effect of humidity condition on sound transmission loss of AAC.

At 75% humidity condition, sound levels inside the chamber were increased from 55.4 dB to 87.6 dB. According to the results, sound levels outside the chamber were reduced compared to inside sound levels with average percentage of about 39.74% by using AAC wall without coating. After applying gypsum coating on AAC wall, measuring process was carried out outside the chamber for 75% humidity condition. An average sound transmission loss of 47.46% was obtained for the same sound levels inside the chamber which were used in pervious tests.

Table 4.3: Sound levels inside and outside the chamber at 75% humidity condition for AAC wall without coating

Inside-sound level (dB)	**Outside-sound level (dB)**
55.4	37.1
65.8	38.7
71.7	40.2
75.5	42.2
79.2	46.3
81.9	48.1
83.7	50.8
84.6	52.7
86.4	54.0
87.6	55.0

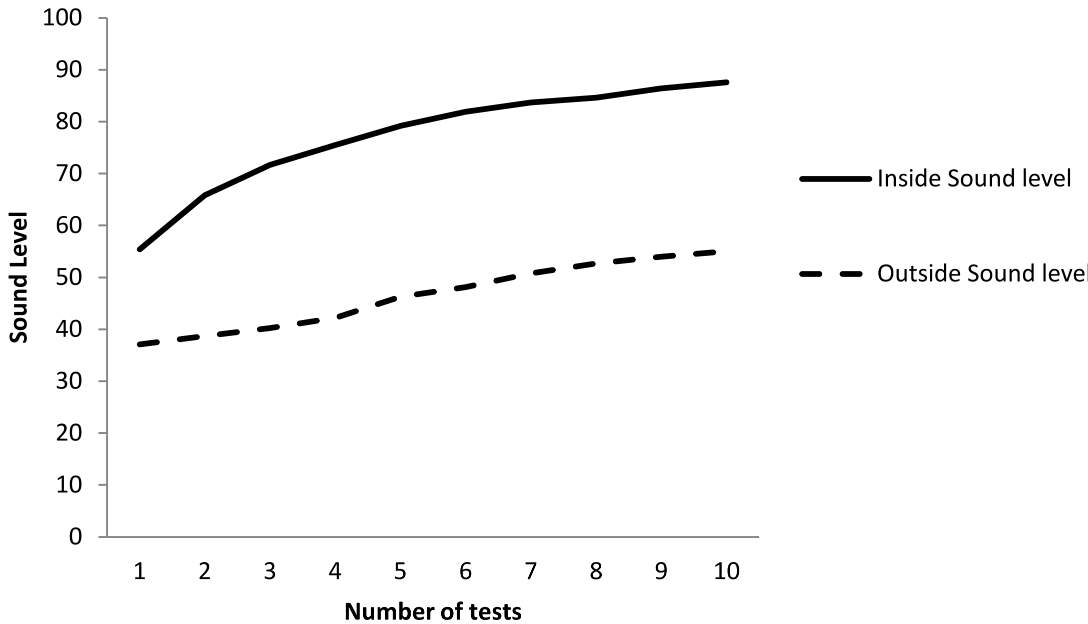

Figure 4.3: Sound transmission loss at 75% humidity condition for AAC wall without coating

Table 4.4: Sound levels inside and outside the chamber at 75% humidity condition for AAC wall with coating

Inside-sound level (dB)	**Outside-sound level (dB)**
55.4	34.8
65.8	35.0
71.7	36.4
75.5	38.1
79.2	39.1
81.9	41.3
83.7	43.2
84.6	45.1
86.4	46.0
87.6	46.5

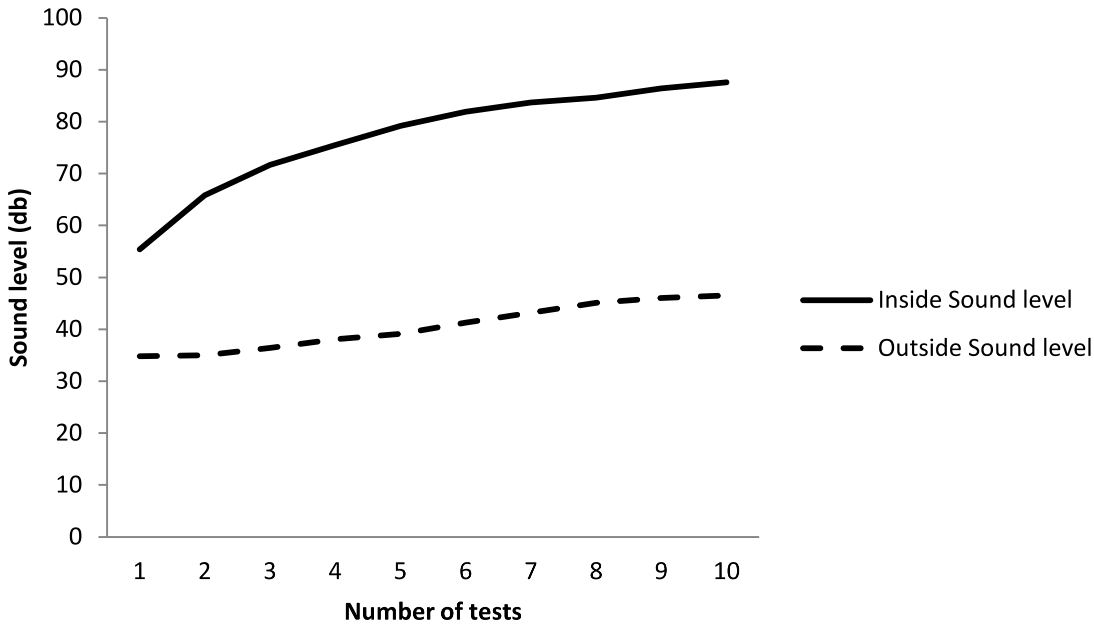

Figure 4.4: Sound transmission loss at 75% humidity condition for AAC wall with coating

With increasing humidity condition inside the chamber up to 100%, sound levels outside the chamber were reduced compared to inside sound level with average percentage of about 37.28% by using AAC wall without coating. With applying gypsum coating on AAC wall an average sound transmission loss of 46.02% was obtained for the same sound levels inside the chamber which were used in pervious tests.

Table 4.5: Sound levels inside and outside the chamber in 100% humidity condition for AAC wall without coating

Inside-sound level (dB)	**Outside-sound level (dB)**
55.4	40.0
65.8	43.5
71.7	44.3
75.5	45.7
79.2	46.8
81.9	48.7
83.7	51.9
84.6	53.1
86.4	54.3
87.6	55.8

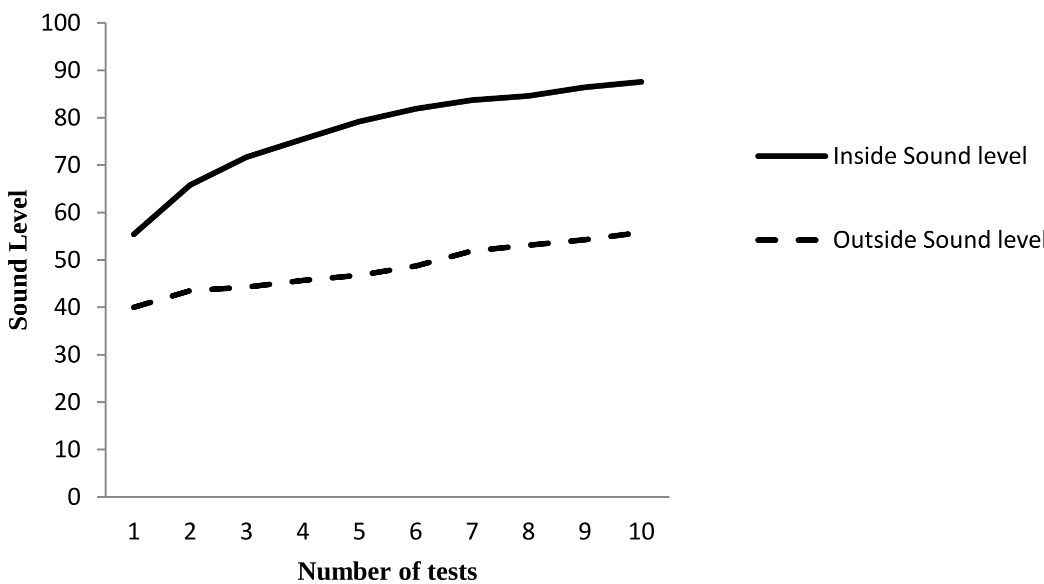

Figure 4.5: Sound transmission loss in 100% humidity condition for AAC wall without coating

Table 4.6: Sound levels inside and outside the chamber in 100% humidity condition for AAC wall with coating

Inside-sound level (dB)	**Outside-sound level (dB)**
55.4	36.0
65.8	36.5
71.7	37.6
75.5	39.1
79.2	41.8
81.9	42.3
83.7	43.8
84.6	45.6
86.4	46.2
87.6	47.7

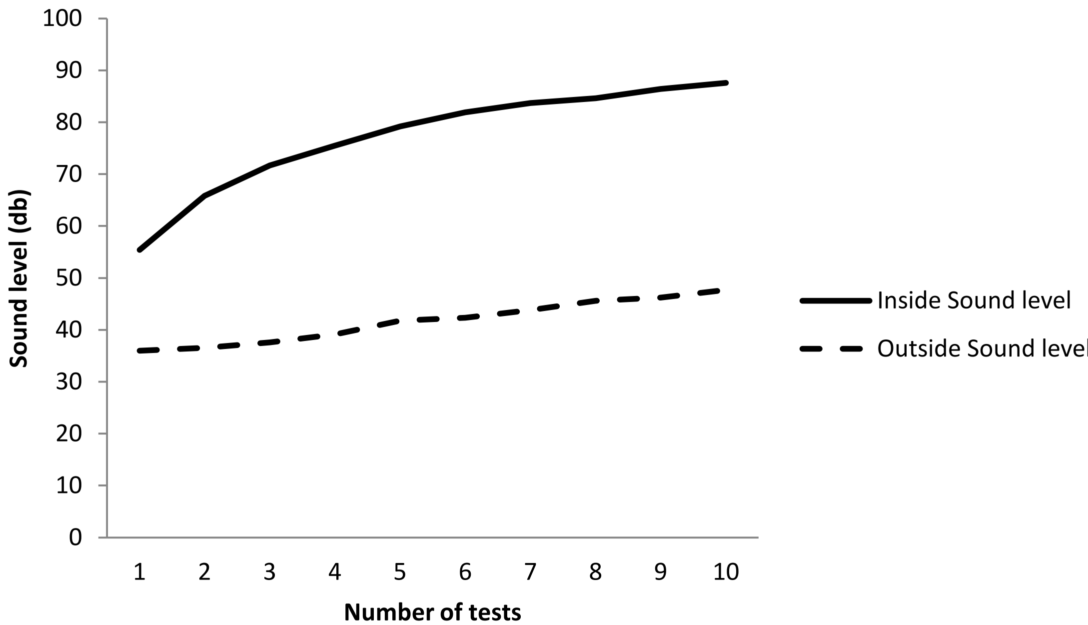

Figure 4.6: Sound transmission loss in 100%humidty condition for AAC wall with coating

According to test results, average sound transmission losses of 37.28% to 48.88% were obtained by using AAC wall in different humidity conditions. Test results indicated that humidity has intrusion effect on sound transmission of AAC walls. Sound waves travel faster in dry air than moist air, because dry air is more dense than humid air and air molecules have higher mass than average water molecules. This effect of humidity on sound speed caused decreasing in sound transmission loss of AAC walls. To counteract this effect gypsum coating was used. Results showed that humidity was less effective on acoustic properties of AAC wall with coating and effect of gypsum coating in sound transmission loss was about 10% on average.

Since AAC is lightweight material with porous structure both plastering and coating have beneficial effects on sound transmission loss because of increasing in air flow resistivity [12].Results indicated that for different sound levels sound transmission losses change parallel to sound levels inside the chamber and it is understandable that there is no resonance in acoustic properties of AAC walls.

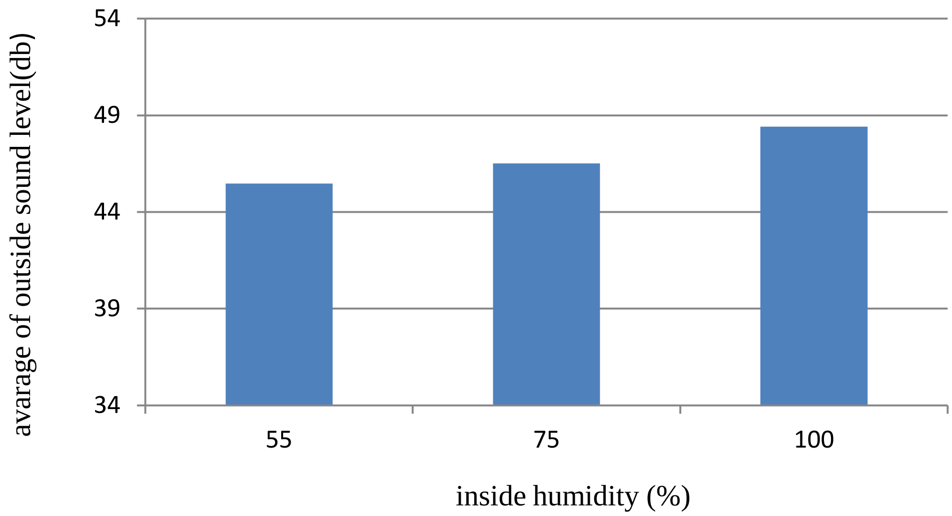

Figure 4.7: Effect of humidity on outside sound levels for AAC wall without coating

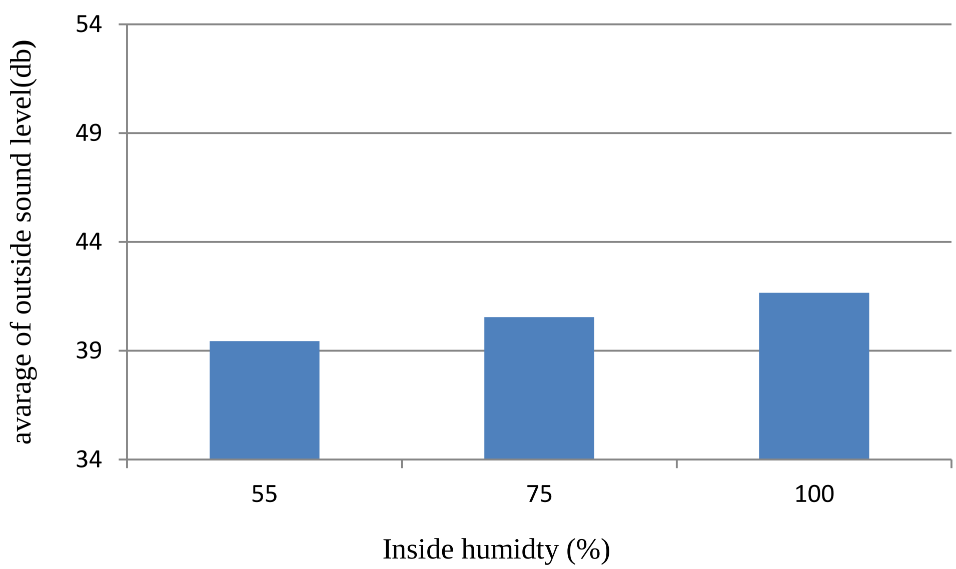

Figure 4.8: Effect of humidity on outside sound levels for AAC wall with coating

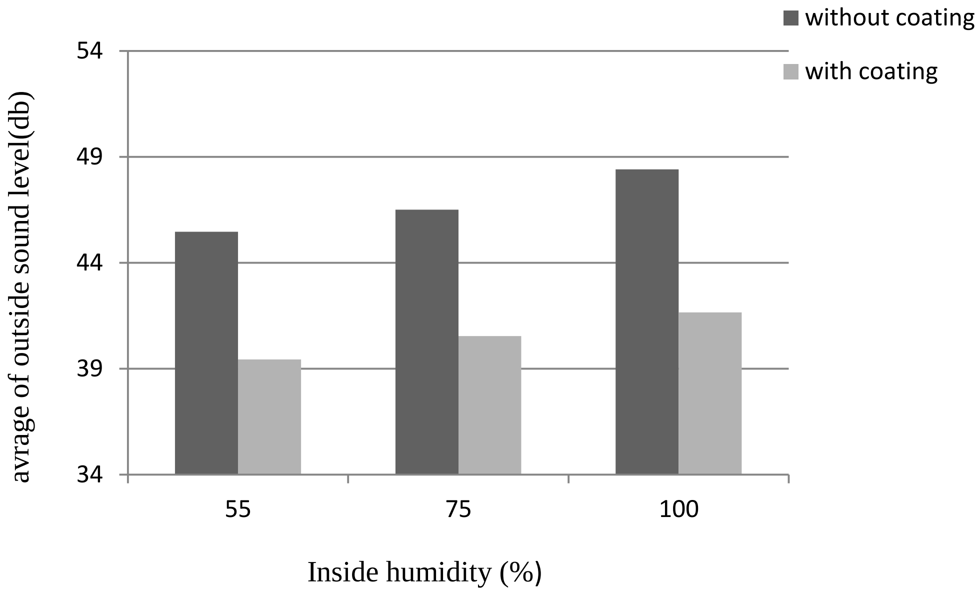

Figure 4.9: Effect of coating in decreasing sound levels

Figure 4.10: Sound level meter

4.2 Thermal Conductivity

Thermal conductivity tests were carried out at three different humidity conditions to determine effects of humidity on thermal properties of AAC panels. The main propose of this test was detecting temperature changes on outside surface of AAC wall when the heating procedure was carrying out inside the chamber. Heating procedures were carried out at three different temperature conditions; each temperature condition was kept constant for duration of 95 minutes.

At 55% humidity condition of inside the chamber, temperature level on the outside surface of AAC wall after 95 minutes of heating procedure with 40°C was increased from 23.2 °C to 24.9°C. After increasing temperature of inside the chamber up to 60 °C, within 95 minutes of heating procedure, temperature on the outside surface of AAC wall increased from 24.9°C to 27.3°C. Third 90 minutes of heating process was carried out when inside temperature was 70°C, after this process temperature on the outside surface of AAC wall was 30.2°C.

After applying gypsum coating on both outside and inside surface of AAC wall heating processes at 55% humidity condition were carried out. At the end of 95 minutes of heating process at 40°C, outside surface of AAC wall's temperature increased from 22.7°C to 23.2°C. Second 95 minutes of heating process started when temperature of inside the chamber was 60°C after this process completed temperature on the outside surface of AAC wall increased from 23.2°C to 25.3°C. With increasing temperature of inside the chamber up to 70°C on the outside surface of AAC wall increased from 25.3°C to 27.1°C after 280 minutes heating process.

Table 4.7: Temperature on surfaces of AAC wall without coating in 55% humidity condition

Time (Minutes)	**Inside Temperature C°**	**Outside Temperature C°**
30	44.3	23.2
60	44.7	24.0
95	45.3	24.9
140	60.0	25.7
170	60.1	26.8
190	60.5	27.3
220	70.3	28.3
250	70.4	29.4
280	74.0	30.2

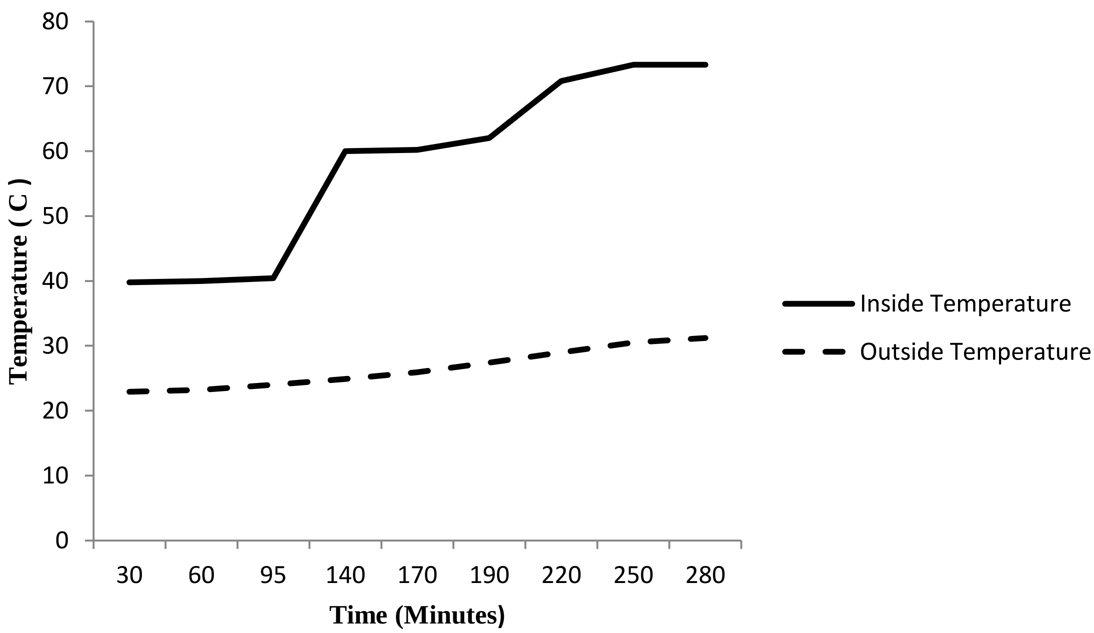

Figure 4.11: Temperature changes inside and outside surface of AAC wall without coating in 55% humidity condition

Table 4.8: Temperature on surfaces of AAC wall with coating in 55% humidity condition

Time (Minutes)	Inside Temperature C°	Outside Temperature C°
30	40.0	22.7
60	40.0	23.0
95	42.0	23.2
140	59.8	24.0
170	61.3	24.7
190	62.0	25.3
220	70.3	26.1
250	70.5	26.5
280	73.3	27.1

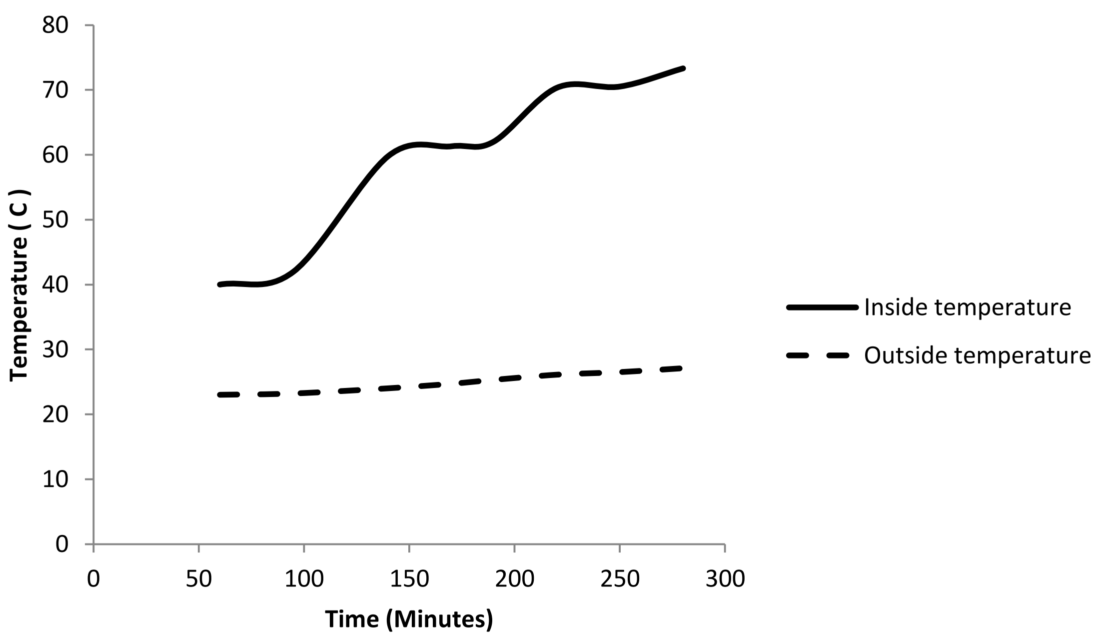

Figure 4.12: Temperature changes inside and outside surface of AAC wall with coating in 55% humidity condition

At 70% humidity condition inside of the chamber, temperature level on the outside surface of AAC wall after 95 minutes heating at 40 °C was increased from 22.9°C to

24°C. After increasing temperature inside of the chamber up to 60°C°, within 95 minutes heating procedure temperature on the outside surface of AAC wall increased from 24 °C to 27.4°C. Third 90 minutes of heating process was carried out when inside temperature was 70°C after this process temperature on the outside surface of AAC wall was 31.2°C.

After applying gypsum coating on both surfaces of AAC wall heating processes at 70% humidity condition were carried out. At the end of 95 minutes of heating process at 40°C, outside surface of AAC wall's temperature increased from 20.5°C to 22.1°C. Second 95 minutes of heating process started when temperature of inside the chamber was 60°C and after this process temperature on the outside surface of AAC wall increased from 22.1°C to 24.6°C .When the temperature of inside the chamber reached to 70°C, the temperature on the outside surface of AAC wall increased from 24.6°C to 27°C after 280 minutes of heating process.

Table 4.9: Temperature measured on surfaces of AAC wall without coating in 70% humidity condition

Time min	**Inside Temperature**	**outside Temperature**
30	39.80	22.9
60	40.0	23.2
95	40.4	24.0
140	60.0	24.9
170	60.2	25.9
190	62.0	27.4
220	70.8	29.0
250	73.3	30.5
280	73.3	31.2

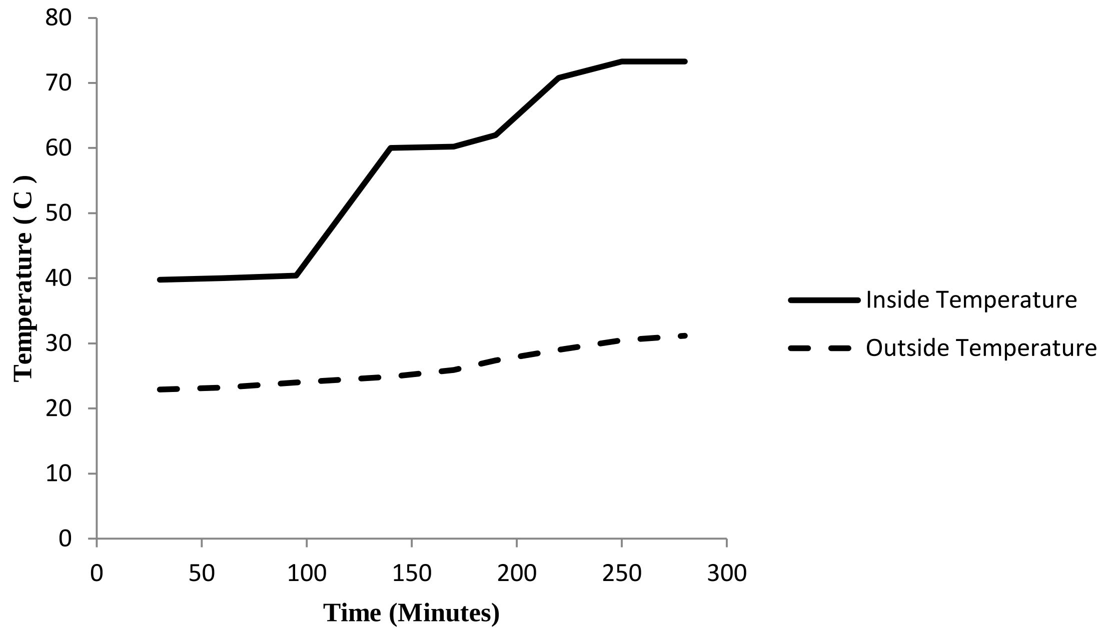

Figure 4.13: Temperature changes inside and outside surface of AAC wall without coating in 70% humidity condition

Table 4.10: Temperature on surfaces of AAC wall with coating in 70% humidity condition

Time min	**Inside Temperature C°**	**Outside Temperature C°**
30	39.8	21.0
60	41.8	21.5
95	42.3	22.1
140	60.0	22.4
170	60.1	23.6
190	62.0	24.6
220	70.0	24.9
250	72.7	25.9
280	73.0	27.0

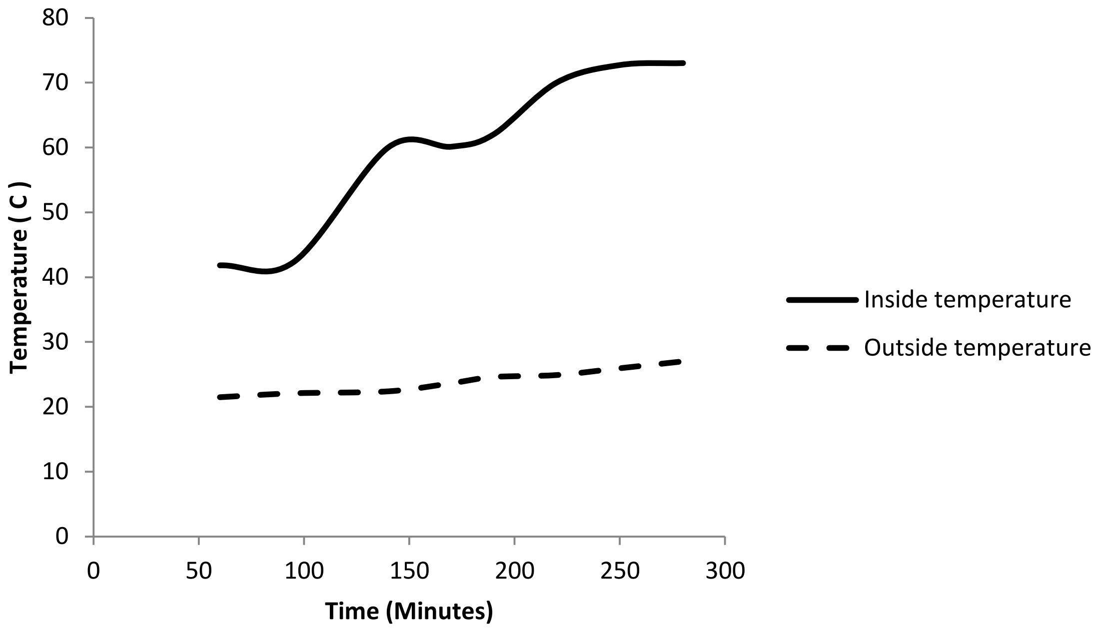

Figure 4.14: Temperature changes inside and outside surface of AAC wall with coating in 70% humidity condition

At 100% humidity condition of inside chamber, temperature level on the outside surface of AAC wall after 95minutes heating procedure at 40°C was increased from 22.7°C to 23.1°C. After increasing temperature of inside the chamber up to 60°C, within 95 minutes heating procedure, temperature on the outside surface of AAC wall increased from 23.1°C to 29°C. The third 90 minutes of heating process was carried out when inside temperature was 70°C and after this process temperature on the outside surface of AAC wall was measured to be 32.3°C.

After applying gypsum coating on both outside and inside surfaces of AAC wall, heating processes in 100% humidity condition were carried out. At the end of 95 minutes heating process at 40°C, outside surface of AAC wall's temperature increased from 23.5°C to 26°C. Second 95 minutes of heating process started when temperature of inside of the chamber was 60°C and after this process completed, the temperature on the outside surface of AAC wall increased from 26°C to 28°C and with increasing temperature inside the chamber up to 70°C the temperature on the outside surface of AAC wall increased from 28°C to 30.7°C after 280 minutes heating process.

Table 4.11: Temperature on surfaces of AAC wall without coating in 100% humidity condition

Time min	**Inside Temperature C°**	**Outside Temperature C°**
30	40.0	22.7
60	40.4	22.9
95	42.0	23.1
140	58.9	25.1
170	60.0	27.6
190	60.0	29.0
220	68.7	30.5
250	70.5	31.5
280	73.0	32.3

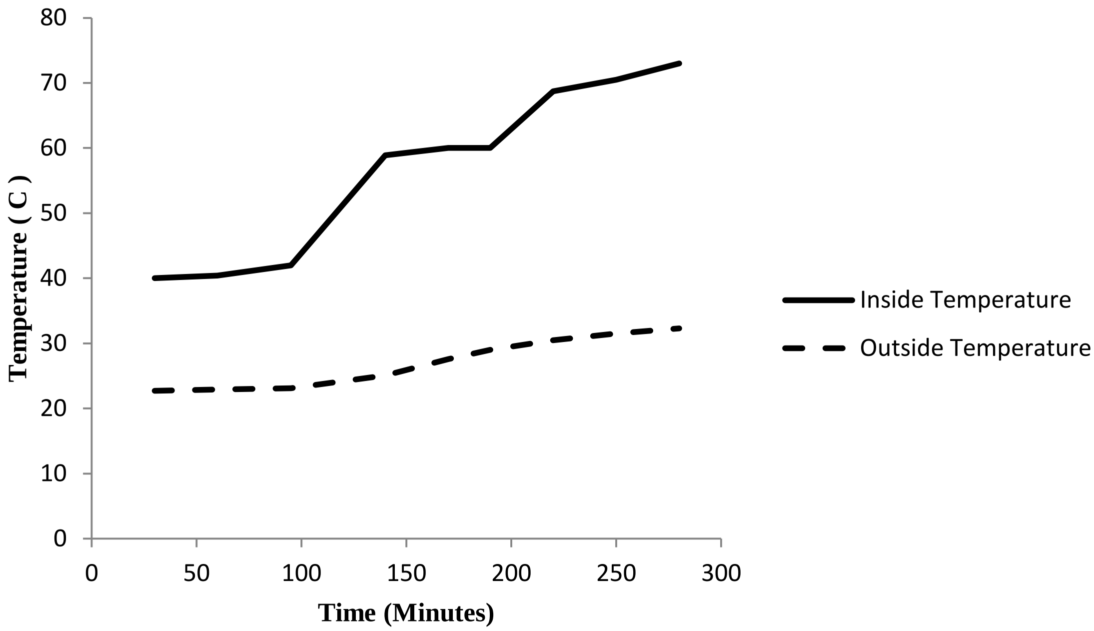

Figure 4.15: Temperature changes inside and outside surface of AAC wall without coating in 100% humidity condition

Table 4.12: Temperature on surfaces of AAC wall with coating in 100% humidity condition

Time min	**Inside temperature C°**	**Outside temperature C°**
30	40.0	23.5
60	40.4	24.7
95	41.3	26.0
140	60.0	27.0
170	60.4	27.3
190	62.0	28.0
220	70.3	28.6
250	70.4	29.0
280	72.0	30.7

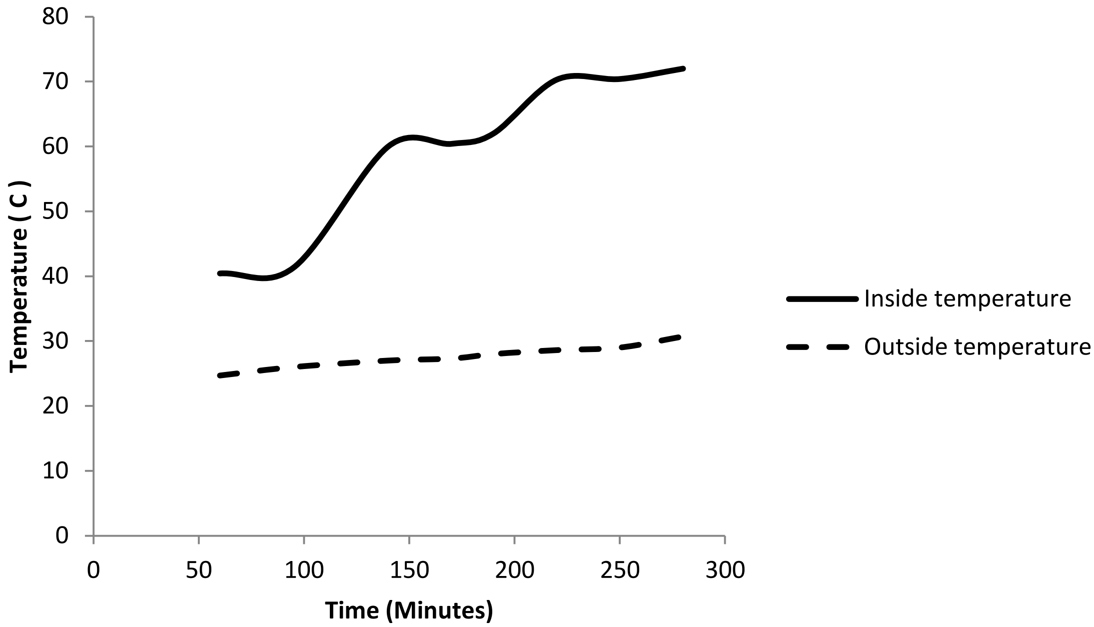

Figure 4.16: Temperature changes inside and outside surface of AAC wall with coating in 100% humidity condition

Humidity and temperature inside the houses are two important factors which can affect comfort and health of habitants. It was reported that temperature of 20°C to 26°C with humidity condition of 30% to 70% are essential for suitable living conditions inside the houses.

According to the test results after 15% to 30% increasing in humidity conditions during testing procedure, that include 280 minutes heating under steady state condition, temperature changes on the outside surface of AAC wall increases with average amounts of 1.3°C and 2.6°C respectively for both with and without coating conditions. After applying gypsum coating on both inside and outside surfaces of AAC wall temperature changes on outside surface of wall decreases with average amount of 2.44°C when it is compared with same humidity conditions for AAC wall without coating. Gypsum coating blocks open pores on surface of AAC wall and prevent air and humidity to penetrate inside of the wall [4].

4.3 Compressive Strength Test

Compressive strength tests were carried out on AAC blocks with 6%, 50% and 100% humidity levels; for each humidity level four 50mm and 150mm AAC cubic samples were prepared.

Average compressive strength of 50mm cubic samples with 6% humidity content was 2.466 MPa. The average compressive strength of 2.608 MPa was achieved for 150 mm cubic samples with 6% humidity content.

Table 4.13: Compressive strength of 50 mm cubic samples at 6% humidity content

Sample	Dim (mm)	V (mm^3)	dry weight (kg)	Dry density (kg/mm^3)	Comp. Dry (MPa)
1	50x50x50	125×10^3	0.057	456×10^{-9}	2.428
2	"	125×10^3	0.057	456×10^{-9}	2.688
3	"	125×10^3	0.057	456×10^{-9}	2.092
4	"	125×10^3	0.057	456×10^{-9}	2.656

Table 4.14: Compressive strength of 150 mm cubic samples at 6% humidity content

Sample	Dim (mm)	V (mm^3)	dry weight (kg)	Dry density (kg/mm^3)	Comp. Dry (MPa)
1	150x150x150	337×10^3	1.385	410.370×10^{-9}	2.529
2	"	337×10^3	1.402	415.407×10^{-9}	2.444
3	"	337×10^3	1.397	413.926×10^{-9}	2.529
4	"	337×10^3	1.381	409.185×10^{-9}	2.929

For 50 mm AAC samples with 50% humidity content average compressive strength of 1.552 MPa was achieved. 150 mm samples with 50% humidity content reached average compressive strength of 1.937 MPa.

Table 4.15: compressive strength of AAC samples with 50% humidity content

Sample	Dim (mm)	V (mm^3)	50% wet weight (kg)	50% wet density (kg/mm^3)	50% wet Comp. (MPa)
1	50x50x50	125×10^3	0.086	688×10^{-9}	1.296
2	"	125×10^3	0.083	664×10^{-9}	1.380
3	"	125×10^3	0.079	632×10^{-9}	1.560
4	"	125×10^3	0.079	632×10^{-9}	1.970

Table 4.16: Compressive strength of AAC samples with 50% humidity content

Sample	Dim (mm)	V (mm^3)	50% wet weight (kg)	50% wet density (kg/mm^3)	50% wet Comp.(MPa)
1	150x150x150	3375×10^3	1.890	560×10^{-9}	2.067
2	"	3375×10^3	1.890	560×10^{-9}	1.973
3	"	3375×10^3	1.900	562.960×10^{-9}	1.907
4	"	3375×10^3	1.910	565.920×10^{-9}	1.800

Average Compressive strength of 50mm samples with 100% humidity content was 1.379 MPa. Average compressive strength of 1.636 MPa was achieved for 150mm AAC samples with 100% humidity content.

Table 4.17: Compressive strength of AAC samples with100% humidity content

Sample	Dim (mm)	V (mm^3)	100% wet weight (kg)	100% wet density (kg/mm^3)	100% wet Comp. (MPa)
1	50x50x50	125×10^3	0.100	800×10^{-9}	1.096
2	"	125×10^3	0.100	800×10^{-9}	1.420
3	"	125×10^3	0.100	800×10^{-9}	1.570
4	"	125×10^3	0.100	800×10^{-9}	1.430

Table 4.18: Compressive strength of AAC samples with100% humidity content

Sample	Dim (mm)	V (mm^3)	100% wet weight (kg)	100% wet density (kg/mm^3)	100% wet Comp. (MPa)
1	150x150x150	3375×10^3	2.310	684.444×10^{-9}	1.636
2	"	3375×10^3	2.290	678.518×10^{-9}	1.676
3	"	3375×10^3	2.295	680×10^{-9}	1.622
4	"	3375×10^3	2.365	700.704×10^{-9}	1.609

According to test results of compressive strength of AAC blocks, decreases observed with increasing humidity content. Because AAC has porous structure and high water content could be absorbed inside the blocks which increases density of blocks and this supplementary humidity content cause sharp decreasing in compressive strength of AAC samples.

Results indicated that 50mm samples absorbed 0.025lit water to reach their 50% saturated condition which caused 38% reduction in their average compressive strength. AAC samples reached their fully saturated weight by absorbing 0.043lit water from its dry state; samples in their saturated state have average of 45% decrease in their compressive strength. Also 150mm samples absorbed 0.505lit water for reaching 50% saturated weight which leaded to 25% reduction in average compressive strength.

Increase in amount of absorption by 0.922lit water brings these samples in their fully saturated state that shows average 38% decrease in compressive strength. To counteract this intrusion effect of humidity, appropriate coating is recommended to block the open pores on the surface of AAC blocks which prevents absorbing of humidity and moisture [4].

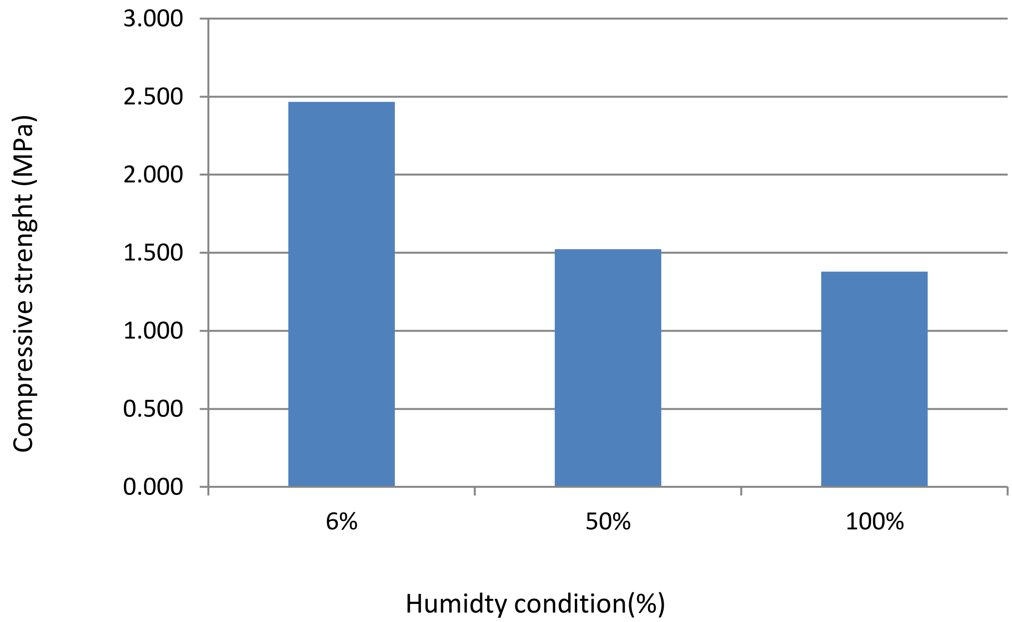

Figure 4.17: Average compressive strength of 50mm cubes

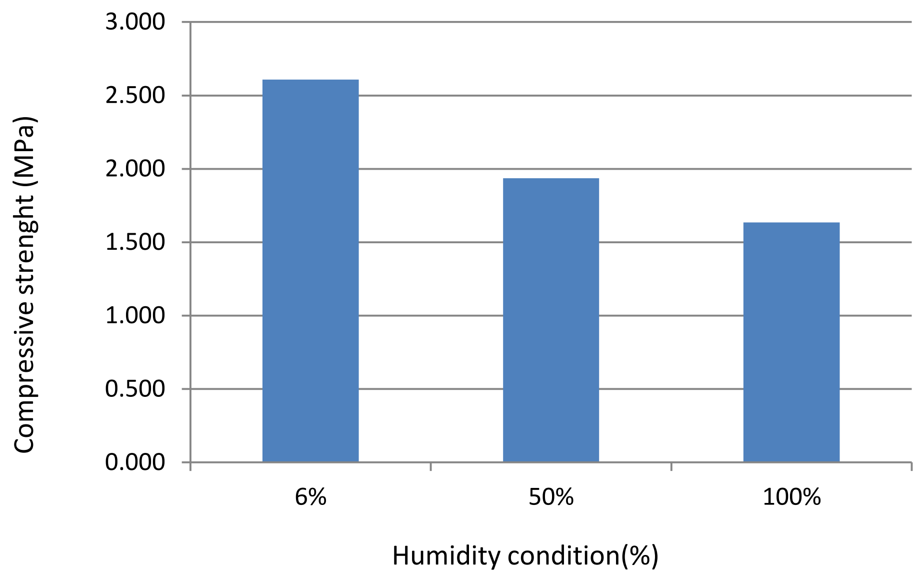

Figure 4.18: Average compressive strength of 150mm cubes

4.4 Flexural Strength Test

Flexural strength tests were carried out on four AAC samples with dimensions of 40mm×40mm×160mm and for these tests concrete beams were loaded with 3 point loading method. Specimens were oven dried before testing to reach their 100% dry condition. According to test results average flexural strength of AAC samples is about 2.013 MPa for average bending moment of 8760 kg-mm. The ratio of the flexural strength to the compressive strength of AAC is about 0.77.

Table 4.19: Flexural strength test results

Sample	Dim (mm)	Flexural Str. (MPa)	Load (kgf)
1	40x40x160	2.096	57
2	"	2.243	61
3	"	1.802	49
4	"	1.912	52
Avg		2.013	54.750

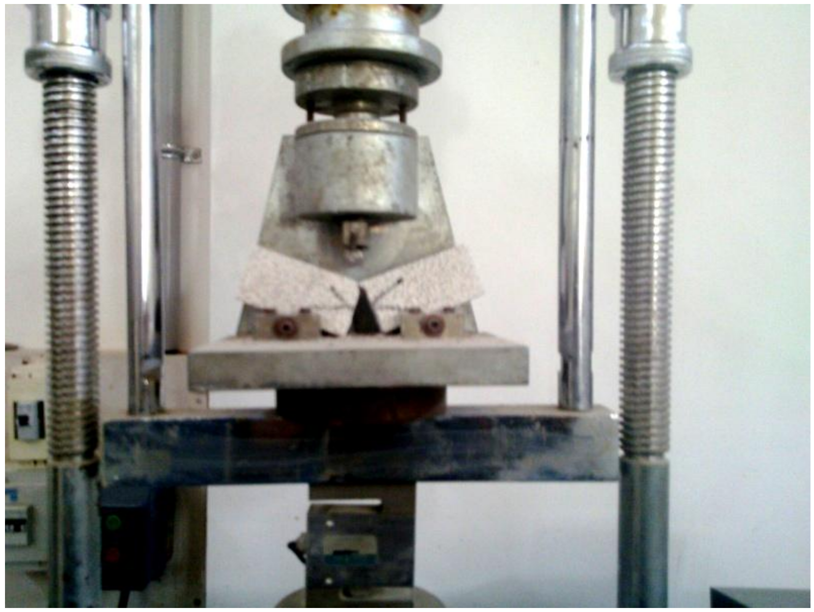
Figure 4.19: Flexural strength test setup

4.5 Water Absorption Test

Water absorption capacity was measured to determine amount of water which can be absorbed by AAC blocks from environment. For this test AAC blocks with dimensions of 150mm and 50mm cubic samples were used. After 96 hours of oven drying process dry conditions of AAC samples were achieved.

The average dry weights of 1.385 kg and 0.057 kg for 150mm and 50mm, respectively was reached after this process. Fully saturated samples were achieved after 96 hours of floating samples inside water tank. Average water contents of 0.954 kg and 0.042 kg were absorbed by 150mm and 50mm samples, respectively during 96 hours to reach their fully saturated condition. Average water absorption percentages of 68%and 73% were also calculated for 150mm and 50mm samples

Table 4.20: Water absorption results of 150mm samples

Sample	Dim (mm)	V (mm^3)	W 96hrs Dry (kg)	W 96hrs wet (kg)	Δ wet(kg)	Δ wet/W 96hrs Dry
1	150x150x150	337×10^3	1.385	2.430	1.045	0.75
2	"	3375×10^3	1.402	2.310	0.908	0.64
3	"	3375×10^3	1.397	2.295	0.898	0.64
4	"	3375×10^3	1.359	2.370	1.011	0.74
5	"	3375×10^3	1.381	2.290	0.909	0.65
Avg			1.385	2.339	0.954	0.684

Table 4.21: Water absorption results of 50mm samples

Sample	Dim(mm)	V(mm^3)	W 96hrs Dry (kg)	W 96hrs wet (kg)	Δ wet(kg)	Δ wet/W 96hrs Dry
1	50×50×50	125×10^3	0.057	0.100	0.043	0.75
2	"	125×10^3	0.057	0.100	0.043	0.75
3	"	125×10^3	0.056	0.092	0.036	0.64
4	"	125×10^3	0.057	0.100	0.043	0.76
5	"	125×10^3	0.056	0.100	0.044	0.78
Avg			0.057	0.098	0.042	0.736

4.6 Fire Resistance Test

Fire resistance test was done to find out effects of different burning temperatures on the properties of AAC samples. For this purpose 50mm cubes were tested at six different temperatures by using an electrical furnace. After fire resistance test, compressive strength test was done to detect effects of fire on strength properties of AAC samples.

After 30 minutes heating procedure at a temperature of 100°C no changes were observed on the appearance of AAC blocks and also no reduction in weight was detected. On the other hand average compressive strength of blocks after fire test was about 2.074MPa which shows a slight decrease comparing to compressive strength of dry state.

Figure 4.20: AAC blocks after heating at 100 °C

Table 4.22: Compressive strength of AAC blocks after fire resistance tests

Sample	Dim (mm)	V (mm^3)	Weight (kg)	Comp. (MPa)
1	50x50x50	337×10^3	0.057	2.090
2	50x50x50	337×10^3	0.057	2.088
3	50x50x50	337×10^3	0.057	2.044

After 30 minutes heating procedure with temperature of 300°C no changes were observed on the appearance of AAC blocks but slight reduction in weight of blocks was detected. On the other hand average compressive strength of blocks after fire test was about 1.809 MPa which shows more decrease in compressive strength comparing to lower temperature heated samples.

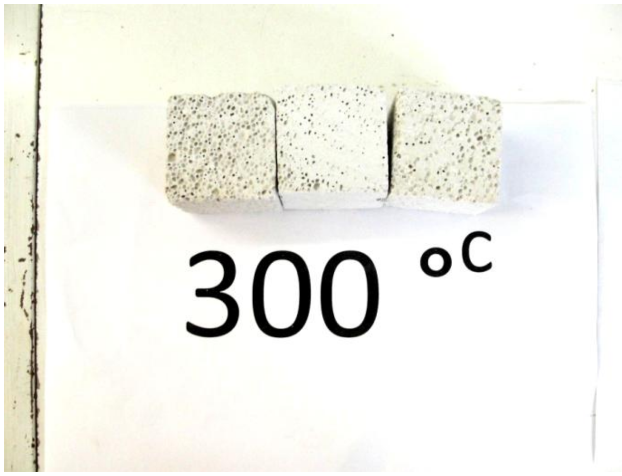

Figure 4.21: AAC blocks after heating at 300 °C

Table 4.23: Compressive strength of AAC blocks after fire resistance tests

Sample	Dim (mm)	V (mm^3)	Weight (kg)	Comp. (MPa)
1	50x50x50	337×10^3	0.0565	1.830
2	50x50x50	337×10^3	0.057	1.820
3	50x50x50	337×10^3	0.055	1.778

After 30 minutes heating procedure at the temperature of 500°C, color of AAC blocks was observed to become darker, and slight reduction in weight of blocks was also detected. On the other hand, average compressive strength of blocks after fire test was about 1.65 MPa which shows more decrease in compressive strength compared to lower temperature heated samples.

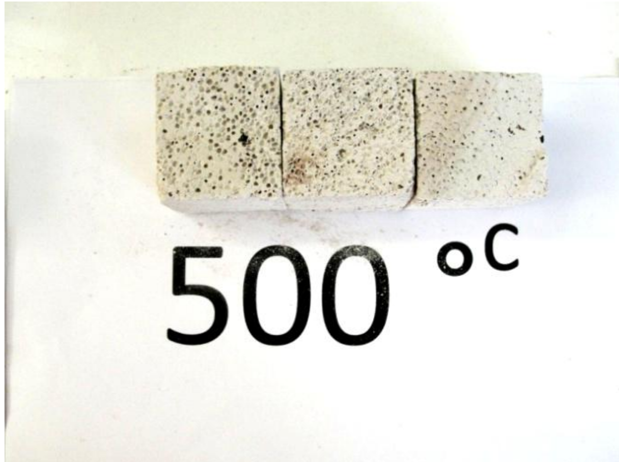

Figure 4.22: AAC blocks after heating at 500°C

Table 4.24: Compressive strength of AAC blocks after fire resistance tests

Sample	Dim (mm)	V (mm^3)	Weight (kg)	Comp. (MPa)
1	50x50x50	337×10^3	0.055	1.628
2	50x50x50	337×10^3	0.055	1.56
3	50x50x50	337×10^3	0.056	1.77

After 30 minutes heating procedure at the temperature of 700°C color of AAC blocks was observed to become darker, also reduction in weight of blocks was detected. On the other hand average compressive strength of blocks after fire test reduced to 1.43 MPa which shows more decrease in compressive strength comparing to lower temperature heated samples.

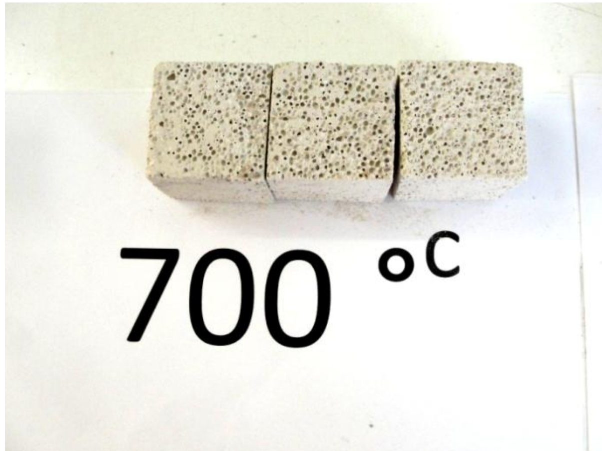

Figure 4.23: AAC blocks after heating at 700°C

Table 4.25: Compressive strength of AAC blocks after fire resistance tests

Sample	Dim (mm)	V (mm^3)	Weight (kg)	Comp. (MPa)
1	50x50x50	337×10^3	0.054	1.42
2	50x50x50	337×10^3	0.053	1.432
3	50x50x50	337×10^3	0.054	1.464

After 30 minutes heating procedure with temperature of 900°C, changes in color from grey to light grey for AAC blocks, became more obvious and in addition to reduction in weight of blocks cracks also appeared on surface of blocks. On the other hand average compressive strength of blocks after fire test reduced to 1.23 MPa which shows more decrease in compressive strength comparing to lower temperature heated samples.

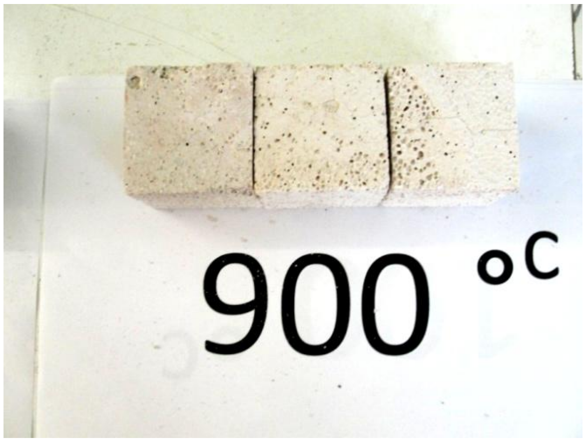

Figure 4.24: AAC blocks after heating at 900°C

Table 4.26: Compressive strength of AAC blocks after fire resistance tests

Sample	Dim (mm)	V (mm^3)	Weight (kg)	Comp. (MPa)
1	50x50x50	3375×10^3	0.052	1.16
2	50x50x50	3375×10^3	0.053	1.268
3	50x50x50	3375×10^3	0.053	1.288

After 30 minutes heating procedure with temperature of 1000°C, color of AAC blocks became bright white and in addition to 0.006 kg reduction in weight of blocks, number of cracks on the surface also increased. On the other hand no compressive strength was obtained for these blocks after heating procedure at a temperature of 1000°C.

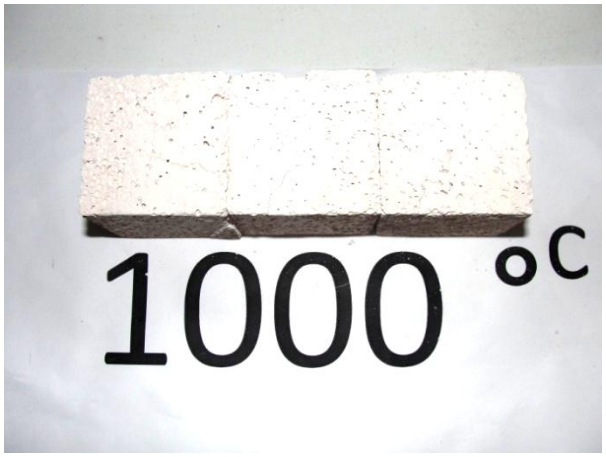

Figure 4.25: AAC blocks after heating at 1000°C

Table 4.27: Compressive strength of AAC blocks after fire resistance tests

Sample	Dim (mm)	V (mm^3)	Weight (kg)	Comp. (MPa)
1	50x50x50	3375×10^3	0.051	0
2	50x50x50	3375×10^3	0.052	0
3	50x50x50	3375×10^3	0.051	0

According to the results increasing the temperature inside the electrical furnace affected color, weight and especially compressive strength of AAC blocks. For each 200°C increases in temperature, average compressive strength of AAC block decreased by about 13%.

According to TS-EN 679 standard optimum humidity content for AAC blocks which are going to be tested under axial load is 6%. On the other hand, with increasing the temperature inside of the furnace humidity content decreased because of evaporation process and caused decreasing in weight of blocks and also some degradation in pore.

Reports state that in concretes with lime and silica based materials changing the temperature causes changes in color of concrete, presence of silica sand and lime in AAC causes these color changes with increasing the temperature inside the furnace [13].

It has to be taken into consideration that this material has good durability and toughness exposed to fire, while test results in this study are showing that AAC has very slight loss in strength when exposed to heat up to 900°C that is the ultimate temperature it can resist. This resistance to high temperature is another advantage that makes AAC an appropriate material to be used in construction bringing satisfaction to engineering expectations that is the safety of users. Structural materials exposed to fire or fire after an earthquake will lose their strength and stiffness because of high temperature however

AAC has proved that can resist high temperatures while keeping its strength, therefore utilizing it in construction can decrease the risk of safety in structure after fire.

Figure 4.26: AAC sample after exposing1000°C under compressive load

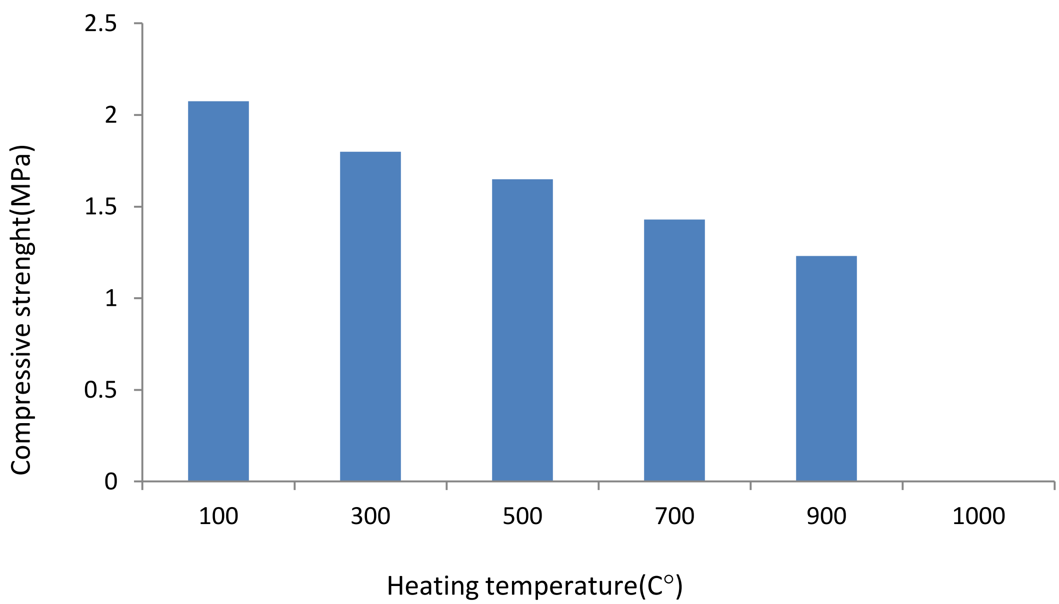

Figure 4.27: Average compressive strength changes with increasing temperature

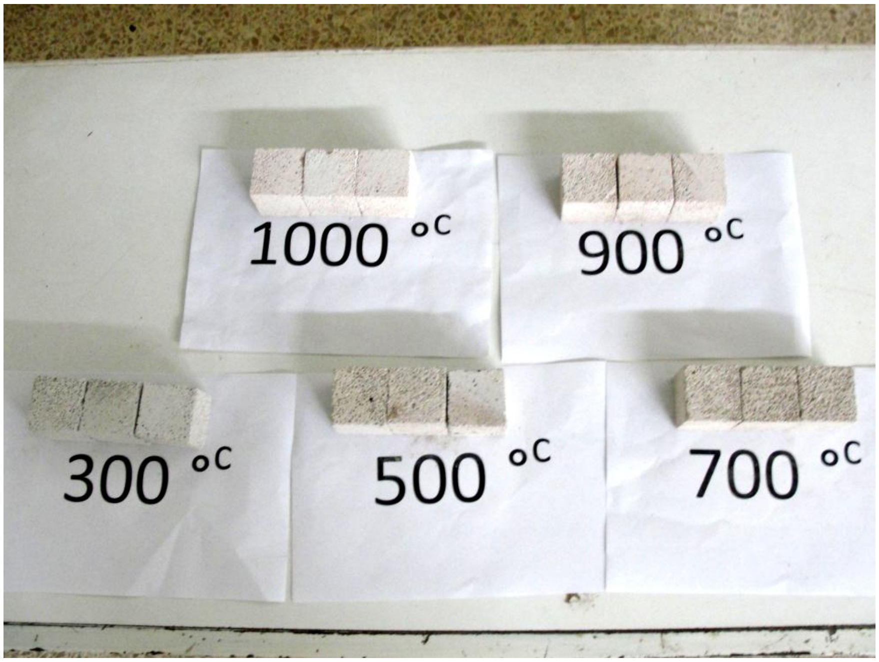

Figure 4.28: Color changes of AAC blocks after heating at different temperatures

4.7 Determination of Coefficient of Thermal Conductivity of AAC walls by using Hot-Box Device

Thermal conductivity coefficient of AAC wall was obtained from experimental research findings. Unit weight of material is the most important influencing factor on thermal insulation capacity. Lower unit weight of material results less coefficient of thermal conductivity which means better heat insulation performance, in other words lighter materials provide better heat insulation characteristics. Furthermore, thermal insulation property of AAC wall systems is closely related to the amount of pores and their distribution. Finer pores provide better insulation performance [4].

Experimental research findings also show that there is a considerable difference between AAC wall system and traditional clay brick wall system based on thermal conductivity coefficient. Thermal conductivity coefficient of 0.0934 was obtained from test results for

AAC wall systems which is 3 times less than wall systems with clay brick. This indicates that AAC wall systems with AAC blocks provide better heat insulation performance comparing to wall systems made with traditional clay brick. Use of autoclaved aerated concrete blocks for the purpose of heating and cooling in residential buildings allows energy savings up to 35% more than other traditional masonry materials.

Chapter 5

CONCLUSION

5.1 Summary of Works Done

Experiments in order to investigate the physical and mechanical properties of autoclaved aerated concrete were carried during this thesis study. Physical properties such as thermal conductivity and sound insulation capacity were evaluated for 3 different temperatures under varying humidity levels for two types of AAC walls (with coating and without coating) ,water absorption capacity of AAC blocks were measured and fire resistance test was carried out for determining the ability of material to withstand fire in six different temperatures increasing from 100°C to 1000°C. Mechanical properties of AAC were evaluated by measuring their compressive strength and flexural strength. Compressive strength test was carried out for 3 different levels of humidity; including fully saturated, 50% relative humidity and oven dried samples with 6% relative humidity. Compressive strength was evaluated for all samples subjected to increasing temperature.

5.2 Conclusions

Results indicated that increasing humidity condition inside the chamber causes reductions in average sound transmission losses of AAC wall, and also for different sound levels, sound transmission losses change parallel to sound levels inside the chamber and it is understandable that there is no resonance in acoustic properties of AAC walls.

According to the test results; increasing in humidity condition inside the chamber during heating procedure under steady state condition causes increase in average temperature change on outside surface of AAC wall.

Compressive strength test results indicated that; increase in amount of absorbed water in AAC causes noticeable reduction in average compressive strength. However strength losses of bigger samples are slightly better than smaller samples, but intrusion effect of humidity is obvious on AAC blocks with different dimensions.

Fire resistance test shows; increasing temperature inside the electrical furnace affected color, weight and especially compressive strength of AAC blocks. Sample color starts becoming darker from its original whitish color as temperature increased up to 900°C, except samples subjected to 1000°C that shows a brighter white color. Weight and compressive strength of all samples started to decrease comparing to their original dry state, this indicates that AAC losses its mass and mechanical properties subjected to increasing heat, it has to be taken to consideration that decrease in the mentioned properties subjected to increasing heat representing fire is acceptable up to 500°C which shows a slight decrease .

5.3 Recommendations

Considering advantages of AAC in energy savings and cost effectiveness it is beneficial to find the way for counteract humidity intrusion effects on AAC’s physical and mechanical properties. According to test results coating and plastering are most important factors for improving resistivity of AAC walls, and these factors help AAC walls to keep their mechanical and physical properties against humidity.

During this thesis study was tried to highlight some weak points of AAC against humidity and also solutions were found to counteract this intrusion effect of humidity on AAC's properties .for future studies it is important to have extensive research of AAC's performance in seismic zones and evaluating acoustic properties of AAC in building close to highways and airports will have remarkable effect on applications of AAC also.

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