THE USE OF ASBESTOS AS A CONSTRUCTION MATERIAL IN PUBLIC BUILDINGS: A CASE STUDY

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ABSTRACT

THE USE OF ASBESTOS AS A CONSTRUCTION MATERIAL IN PUBLIC BUILDINGS: A CASE STUDY

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Since the beginning of the 20th century, asbestos minerals due to its physical and chemical properties were used in many industrial areas, especially construction. Despite its common preference in industry, carcinogenic effects of asbestos on health were identified. Therefore, use of asbestos minerals was forbidden worldwide. Nevertheless, at present, the negative health effects become a significant issue because of urban transformation projects, even in Turkey. The main objective of this study is to assess construction materials within the scope of asbestos usage in the public buildings. The research methodology followed in this study has two main stages as field and laboratory work. In the first stage, 10 public buildings built between 1960 and 1980, were selected at 5 different locations in Ankara. A total of 150 samples which include wall, floor coverings and insulation materials, were taken from these buildings. The second stage of the research was conducted at the laboratory to examine the samples mineralogically and petrographically. The samples firstly were grouped based on the density of fibrous content under stereo microscope. Following this step, asbestos content and type were examined by polarized light microscope. Research findings revealed that asbestos is present in 47% of 150 samples. Moreover, asbestos minerals were used not only in insulation materials, but also in wall and floor materials. The obtained results indicate the existence of all six asbestos types including the most risky ones as amosite and crocidolite for human health. The main novelty of this thesis study is that it clarifies the use of asbestos as construction materials to be more than it is estimated. This research, moreover, expand asbestos awareness, and make generalization for the asbestos risk assessment use before demolition and maintenance-repair processes in Turkey, in order to protect both employee and public health.

Keywords: Asbestos Types, Construction Materials, Occupational Health and Safety, Public Buildings, Risk Assessment.

ÖZ

KAMU BİNALARINDA YAPI MALZEMESİ OLARAK ASBESTİN KULLANIMINA İLİŞKİN VAKA ÇALIŞMASI

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Asbest mineralleri, fiziksel ve kimyasal özellikleri nedeniyle 20. yüzyılın başından itibaren, özellikle yapı sektörü olmak üzere bir çok endüstriyel alanda kullanılmıştır. Endüstride yaygın olarak tercih edilmesine rağmen, asbestin sağlık üzerindeki kansorejen etkisi tanımlanmıştır. Bu nedenle, dünya genelinde asbest minerallerinin kullanımı yasaklanmıştır. Ancak, Türkiye'de günümüzde kentsel dönüşüm projeleri sebebiyle asbestin sağlığa olumsuz etkisi gündeme gelmiştir. Bu çalışmanın asıl amacı, kamu binalarında asbest kullanımı amacıyla yapı malzemelerini incelemektir. Tez çalışması süresince, saha ve laboratuvar çalışması olarak iki aşamalı araştırma metodolojisi uygulanmıştır. İlk aşamada, Ankara'da 5 farklı yerleşkede bulunan 1960-1980 tarihleri arasında yapılmış 10 kamu binası seçilmiş olup; bu binalardan, duvar, yer kaplaması ve yalıtım malzemesinden oluşan toplamda 150 numune alınmıştır. Araştırmanın ikinci aşaması ise numunelerin mineralojik ve petrografik incelenmesi için laboratuvar ortamında yürütülmüştür. Numuneler öncelikli olarak, stereo mikroskop altında incelenerek lifli yapılarının yoğunluğuna göre sınıflandırılmışlardır. Sonraki adımda ise, polarize ışık mikroskobu altında numunelerin asbest içerikleri ve türleri incelenmiştir. Araştırma bulguları, 150 numunenin %47'sinde asbest olduğunu göstermektedir. Ayrıca, asbest minerallerinin sadece yalıtım malzemelerinde değil duvar ve yer malzemelerinde de kullanıldığı tespit edilmiştir. Elde edilen sonuçlar, numuneler içerisinde, insan sağlığı açısından

en riskli olan asbest türlerinden amosit ve krosidolit dahil tüm altı asbest tipinin de bulunduğunu ortaya koymaktadır. Bu tez çalışmasının asıl yeniliği, yapı malzemesi olarak kullanılan asbestin tahmin edilenden daha çok olduğununu açık bir şekilde anlatmaktır. Üstelik bu araştırma, asbest farkındalığını arttırarak, Türkiye'deki yıkım ve bakım-onarım süreçlerinden önce, hem çalışan hem de halk sağlığını korumak için asbest risk değerlendirmesinin uygulanmasının önemini vurgulayacaktır.

Anahtar Kelimeler: Asbest Türleri, İş Sağlığı ve Güvenliği, Kamu Binaları, Risk Değerlendirmesi, Yapı Malzemeleri

To my lovely deceased grandmother, memories of whom still give me strength…

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One final word for my cats, İncir Fiq and Erik Kumbull, thank you for being a pacificator for me during my writing process.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS

ACMs: Asbestos-containing materials

F: Floor

I: Insulation

ILO: International Labour Organization

OHS: Occupational Health and Safety

PLM: Polarized Light Microscopy

RI: Refractive Indice

SEM-EDS: Scanning Electron Microscope with Energy Dispersive Spectrometer

SM: Stereo Microscopy

TEM: Transmission Electron Microscope

VFC: Vinyl Floor Covering

W: Wall

WHO: World Health Organization

XRD: X-Ray Diffractometer

CHAPTER 1

INTRODUCTION

1.1. Background Information

Asbestos is a commercial name given to mineral groups consisting of fibrous minerals. It is found in 3000-4000 commercial goods from automobiles to the ship industry, textile to the paper industry (Dodson and Hammar, 2006). As a result of a factor of ease during production, as well as its physical and chemical properties, asbestos came to be used as construction materials on buildings since the beginning of 1900s (Woodson, 2012). Due to its high heat resistance, it was used in fire doors and on heating installations of buildings. Moreover, because of its high mechanical strength and hardenability, it was used in roof and wall cement. Asbestos is a very good isolation material, and correspondingly, it had a wide range of use in the construction area, such as vinyl floor covering (VFC), glass putty, fuse box, ceiling covering, etc. (HSE, 2013).

In the late 1970s, the negative effects of asbestos on human health were discovered. During this time, asbestos was used for many years. Throughout the first period of utilization, asbestos was referred to as “miraculous”; however, after the negative effects on human health became apparent, this material came to be known as “deadly”. The difference between denotations of asbestos could be seen on the public posters of different eras (Figure 1.1). After asbestos types were labeled as “deadly minerals”, their removal, processing and sale and usage in building material were prohibited in many countries. Although fully banned in developed countries, it is still known to be used in under-developed countries.

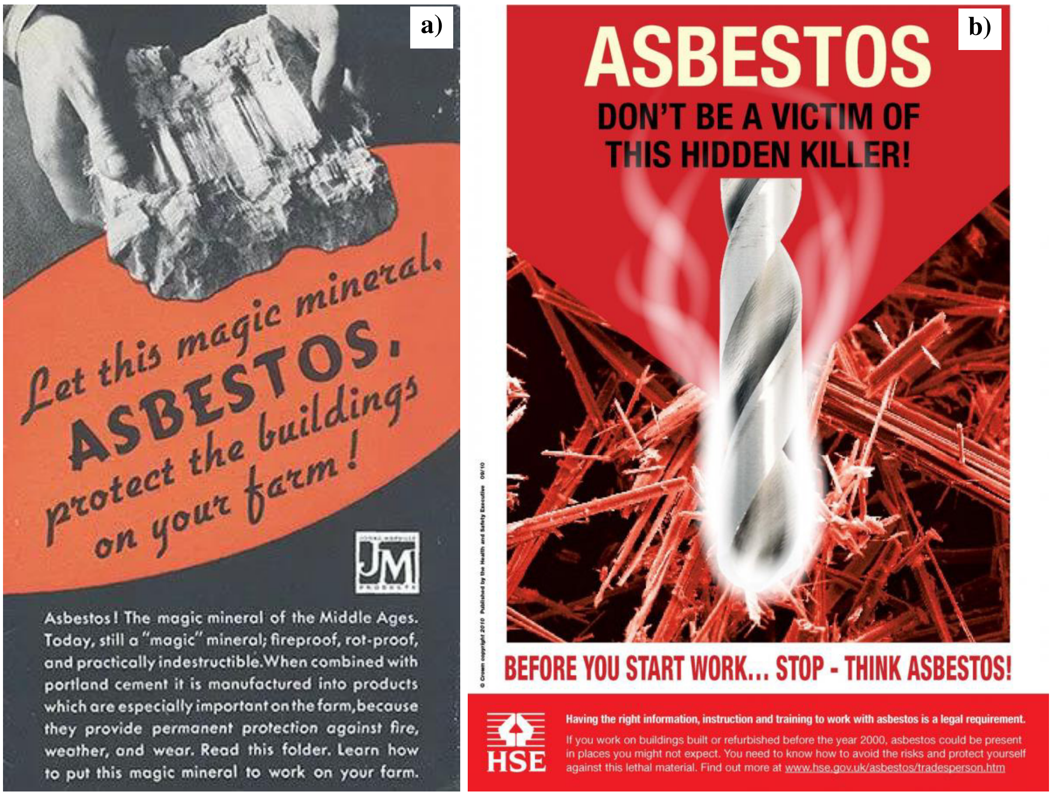


Figure 1.1. Two contrasting posters about asbestos utilization shows the change in the attitude with time; a) previously (before 1970s) b) nowadays (after 2010s) (a) URL-1 b) URL-2)

1.2. Statement of the Problem

It is widely accepted that asbestos was used in all buildings built in the UK before 2000. Consequently, all demolition, maintenance and repair plans were evaluated according to the presence of asbestos (HSE, 2018). Despite prohibition of asbestos usage in present, there can be a possibility of asbestos exposure for the people who work for long time in old public buildings. In Figure 1.2, the hidden threat of asbestos is mentioned in UK as newspaper news. This report shed light to the asbestos effects being more than predicted nowadays.

Figure 1.2. Two headlines from UK related to asbestos treat (The Times, 2019)

Asbestos types, which were widely used as construction materials in public buildings in Turkey, were completely banned in 2010 (MLSS, 2017). Considering the use of asbestos in public buildings such as schools, hospitals, ministries and embassies rather than the houses built before 2010, the presence of asbestos should be examined and the maintenance and repair needs of the buildings should be evaluated within the scope of Occupational Health and Safety.

Asbestos-containing materials (ACMs) were used as construction material especially for thermal isolation of pipe systems in buildings. In addition to thermal isolation; it was widely used in electrical and sound insulation, decorative plasters, roofing and flooring products (HSA, 2013). The ACMs in the non-residential building are shown in Figure 1.3.

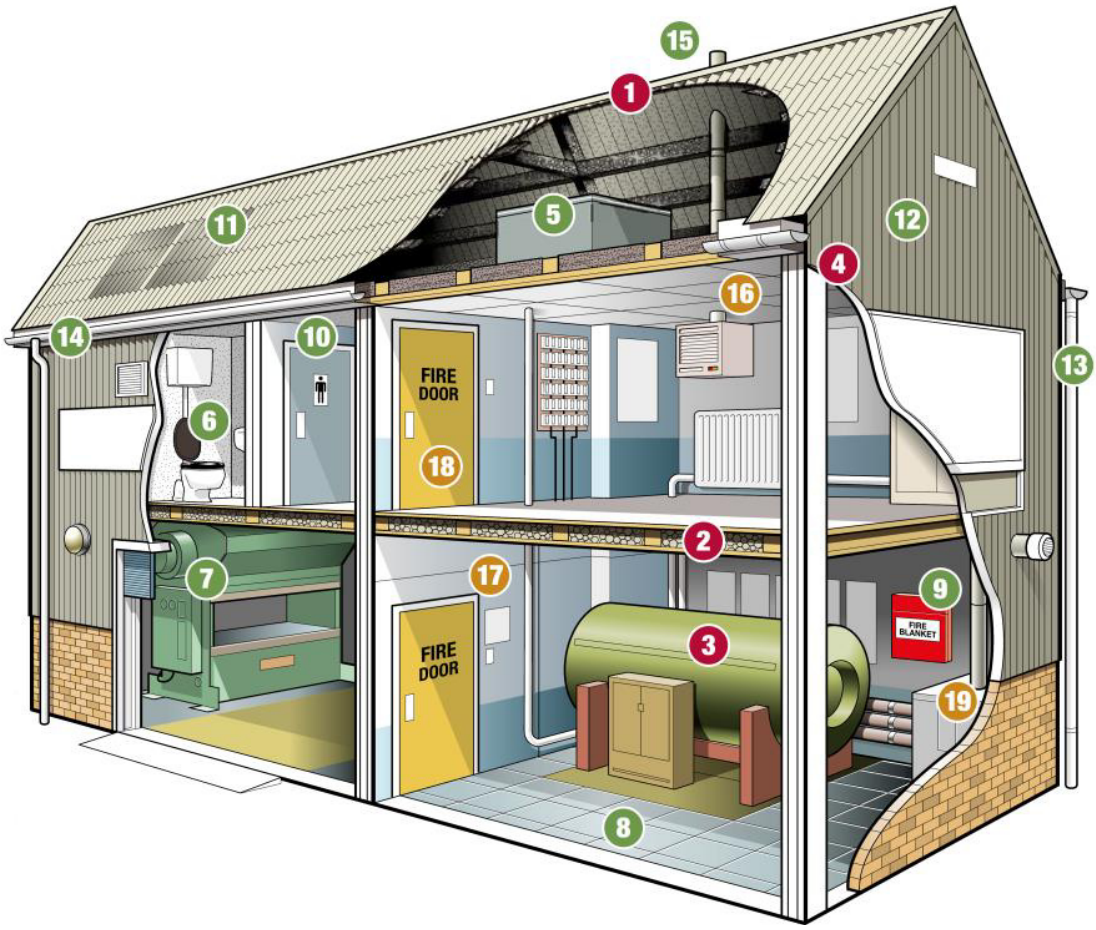


Figure 1.3. Asbestos-containing materials; 1) Sprayed coating on ceilings, walls, beams and columns; 2) Loose fill insulation; 3) Lagging on boilers and pipes; 4) Asbestos insulating boards soffits; 5) Asbestos cement water tank; 6) Toilet seat and cistern; 7) Asbestos rope seals, gaskets and paper; 8) Vinyl floor tiles; 9) Textiles e.g. Fire blankets; 10) Textured decorative coating on walls and ceiling; 11) Asbestos cement roof; 12) Asbestos cement panels; 13) Asbestos cement gutters and downpipes; 14) Asbestos cement soffits; 15) Asbestos cement flue; 16) Asbestos insulating boards ceiling tiles; 17) Asbestos insulating boards partition walls; 18) Asbestos insulating boards panels in fire doors; 19) Asbestos insulating boards around boilers, storage heater and warm air heating systems (from HSE, 2018)

Such widely used materials were used both in residential and industrial constructions in Turkey similar to many other countries. Maintenance and repair employees are exposed to the asbestos in the old buildings and the other employees are exposed if there is any repairing area next to their workplaces or working in a damaged work area. Currently in Turkey, within the scope of legal regulations related to Law no. 6331, building materials containing asbestos are usually inspected before a building is demolished. For asbestos building materials, which are covered by our legislation, asbestos inventory studies are not deemed to be important. In actuality, it is of great importance to protect employee health in case of possible activation.

The urban transformation came to be a part of the Turkish agenda thanks to the scope of Statute No. 6306, which was adopted in 2012. Moreover, by means of this law, risky buildings were planned to be demolished. The demolition process of these buildings has to be handled specifically as the buildings contained asbestos materials. Today, regulations and trainings are organized in our country for the problem of asbestos brought up by urban transformation. Asbestos materials, which are solely important in the case of demolition of buildings, should also be considered in the maintenance and repair of buildings. Even the exposure of people living / working in an area with asbestos activation, which is a phenomenon caused by existing deformations in the buildings, should be evaluated.

1.3. Objectives and Scope of the Study

The purpose of this thesis is to investigate the presence of asbestos minerals commonly used in construction materials before the 1980s due to their physical and chemical properties, and to conduct the asbestos risk assessment for demolition and maintenance-repair priorities.

Also, the main scope of this research consists the determination of correct asbestos types in 10 different public buildings in other words, non-residential buildings, constructed between 1960 and 1980 in Ankara. The focus is on these selected buildings from 5 different locations in order to predict the health effects of related employees in relation to occupational health.

In addition, it aims to determine the risky areas and to give suggestions about necessary precautions to be taken during any maintenance-repair and demolition procedures, after detailed investigation and sampling as field work, and mineralogical characterization of the samples as laboratory work are finished.

Furthermore, the objective of this thesis is to evaluate the subject of occupational exposure from a different point of view and to emphasize the importance of the authorized persons not only during the dismantling of the asbestos, but also for further proactive approach.

1.4. Research Methodology

The methodology of this thesis is based on dedective approach in order to confirm/reject the assumptions related to asbestos presence in the buildings. There are two main stages which are conducted for investigation of asbestos in the buildings after selecting the pilot region: 1) field work as qualitative research, 2) laboratory work as semi-quantitative research.

The first stage began with investigation studies that aim identification of current state and the right place for collecting the samples. The workplaces were evaluated in terms of their deformations in risk rating part of the thesis that follows the investigation studies. During sample collection, many of the taken samples had dimensions dictated by deformation of the structure, as generation of new deformations was avoided. For this reason, weight and volume of the samples was ignored during collection process. The samples representing wall, floor and insulation materials were collected.

For the second stage, although there are several analytical methods used for identifying asbestos types correctly, the principal methods, stereo microscope (SM) and polarized light microscope (PLM) were used. These methods are commonly used for bulk samples. The other method is transmission electron microscope (TEM) that is used to identify asbestos in air samples, or even in water samples. Moreover, X-ray diffractometer (XRD) and scanning electron microscope with energy dispersive spectrometer (SEM-EDS) are commonly used to identify asbestos types. Even though SEM images of fibrous minerals are similar (Figure 1.4), semi-quantitative chemical measurements by EDS result in identification of different types, as well as XRD.

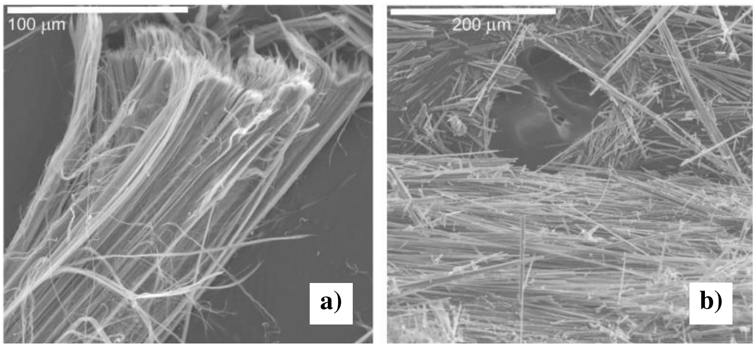


Figure 1.4. SEM views of asbestiform minerals; a) Chrysotile, b) Anthophyllite (Van Gosen, 2007)

In this research, the collected samples were examined microscopically in a laboratory. Whole samples, which are bulk materials, were powdered before laboratory studies to be analyzed under microscope. The laboratory studies, which happens to be the second stage, were performed by Stereo Microscope and Polarized Light Microscope.

Fisrtly, the bulk samples were examined with stereo microscope in order to find the fibrous form in the specimens. The classification method, conducted by quantification based on visual estimation to explain the density of fibrous materials, was applied during this step of the study. The defined classification was used in the rest of the steps along this study as well. In this classification, if there was no fibrous material identified in a sample under the stereo microscope, a cross symbol was attributed to that sample. On the other hand, if there was fibrous material in a sample, varying number of check marks was given to that sample according to its density. If the percentage of fibrous material in bulk sample was between 1 and 25, 26 and 50, 51 and 75, 76 and 100; one check mark, two check marks, three check marks and four check marks were attributed respectively for the sake of classification (Table 1.1).

Table 1.1. *Fibrous material content-based classification of the studied samples*

Classification	**Concentration (%) in bulk sample**
✕	0
✓	1 – 25
✓✓	26 – 50
✓✓✓	51 – 75
✓✓✓✓	76 – 100

Following the Stereo Microscopic study, Polarized Light Microscope (PLM) was used for petrographic analysis. PLM analysis was conducted for samples with two, three and four check marks according to the classification of the samples in Table 1.1.

Optical properties of asbestos minerals were utilized for accurate determination of asbestos types. Refractive indices (RI) of the asbestos minerals are critical in distinguishing the varieties (Table 1.2). Moreover, color and pleochroism, birefringence, extinction characteristics and sign of elongation are used to identify the fibers (CEPA, 1991).

Table 1.2. *Refractive indices of the asbestos minerals (Su, 2003)*

Mineral	**Refractive index liquid used**
Chrysotile	1.550
Tremolite	1.620
Actinolite	1.625
Anthophyllite	1.625
Amosite (Grunerite)	1.680
Crocidolite (Riebeckite)	1.700

RI of an unknown mineral is determined by the Becke Line Test using liquids with known RI. Becke Line is the blur of boundary between balsam and mineral. The Becke Line Test explains that if the boundary blur of mineral goes towards to the balsam, balsam's refraction is greater than the mineral's and vice versa (Kerr, 1977). A sufficient amount from each of the powdered samples was placed on a glass slide and mixed with a liquid with the most appropriate RI to determine the RI of the fibers under PLM. In this study, the value of selected liquid's n_{α} was 1.620 that provide significant clue about variety of asbestos, also in addition to RI, the other optical properties, that are color, pleochroism, birefringence, extinction characteristics and sign of elongation, were examined to determine asbestos type. Thus, the identification of the minerals in the samples was done based on the optical properties given in Table 1.3.

Table 1.3. *Optical properties of asbestos minerals (NIOSH, 1994)*

<table>
<tr><th>Mineral</th><th>Morphology of the fiber</th><th>Color and pleochroism</th><th>Birefringence</th><th>Extinction characteristics</th><th>Sign of elongation</th></tr>
<tr><td>Chrysotile</td><td>- Wavy fibers with kinks. Splayed ends on larger bundles.

- Aspect ratio typically >10:1</td><td>- Colorless to light brown upon being heated.

- Nonpleochroic.</td><td>0.002 - 0.014</td><td>Parallel to fiber length</td><td>+ (length slow)</td></tr>
<tr><td>Tremolite</td><td rowspan="2">- Straight and curved fibers. Cleavage fragments common. Large fiber bundles shows splayed ends.

- Aspect ratio generally <10:1</td><td>Colorless.</td><td rowspan="2">0.02 - 0.03</td><td rowspan="2">Oblique - 10 to 20E for fragments. Some composite fibers show 5 extinction</td><td rowspan="2">+ (length slow)</td></tr>
<tr><td>Actinolite</td><td>- Green

- Weakly to moderately pleochroic.</td></tr>
</table>

Table 1.3. *(continued)*

Mineral	Morphology of the fiber	Color and pleochroism	Birefringence	Extinction characteristics	Sign of elongation
Anthophyllite	- Straight fibers and fiber bundles. Cleavage fragments may be present. - Aspect ratio generally <10:1	- Colorless to light brown. - Nonpleochroic to weakly pleochroic.	0.019 - 0.024	Parallel to fiber length	+ (length slow)
Amosite (Grunerite)	- Straight fibers and fiber bundles. Bundle ends appear broom-like or splayed. - Aspect ratio typically >10:1	- Colorless to brown upon heating. - May be weakly pleochroic.	0.02 - 0.03	Parallel to fiber length	+ (length slow)
Crocidolite (Riebeckite)	- Straight fibers and fiber bundles. Longer fibers show curvature. Splayed ends on bundles. - Aspect ratio typically >10:1	- Characteristic blue color. - Pleochroic.	0.014 - 0.016 Interference colors may be masked by blue color.	Parallel to fiber length	- (length fast)

1.5. Expected Contributions

This research is expected to increase awareness of presence asbestos in old buildings and to promote rigorous inspection prior to demolotion. Also, it attempts to emphasise the importance of generation of asbestos inventory of the buildings before demolition and maintanence-repair.

This study includes asbestos risk ratings of the occupational health and safety of selected public buildings in pilot areas and is a pioneering study on the importance of accurate identification of asbestos inside the construction material. Furthermore, it seeks to explain the significance of correct determination of asbestos type for both public and occupational health.

There are two exposure types to asbestos cited in literature which are environmental and occupational exposure. This kind of study, which is investigated under the title of "third exposure", besides the two accepted exposure types, due to the asbestos content in building materials, was not conducted before. The research is also expected to contrubite to the literature by evaluating it from the medical geology perspective, which is the most specialized area for the determination of presence of asbestos, as well as the establishement of the relationship between mineral types and health.

1.6. Outline Thesis

This thesis is composed of six subsequent chapters. Chapter 1 is an introduction chapter which includes background, statement of the problem, objectives and scope of the study, research methodology and expected contributions of the thesis. In Chapter 2, the most relevant studies about the topic are presented in detail. The main part of study that is asbestos characterization in construction materials is explained in Chapter 3. The obtained findings were used for asbestos risk assessment and were presented in Chapter 4. In Chapter 5, all the results are combined and discussed thoroughly. Finally, conclusions drawn from the results and recommendations for the future studies are stated in Chapter 6.

CHAPTER 2

LITERATURE SURVEY

2.1. Introduction

For the reason that there are not specific studies related to asbestos usage in public buildings in the literature, the previous studies related to asbestos were categorized into three main topics in this chapter. Firstly, mineralogical definition was explained, and then health effects was presented. Asbestos risk assessment was given with its sub-sections in the end of the chapter.

2.2. Mineralogical and Commercial Definition of Asbestos

Discovery and use of rocks hosting asbestos by human-beings extend back to thousands of years (Van Gosen, 2007). “Asbestos” is a commercial nomenclature rather than a mineralogical definition. In this thesis, the term “asbestos” is used in a general sense because of its industrial usage in constructions. In this section, however, geological and mineralogical properties of the minerals, accepted as asbestos, are summarized because they are chemically distinct and their effects on health are different.

There are many minerals with fibrous texture, but not all of them are accepted to be asbestos. All fibrous asbestos minerals are hydrous silicate minerals that belong to serpentine and amphibole groups. These two main groups are distinguished by their distinct physical and chemical properties, and are Chrysotile from the Serpentine group, and Amosite, Crocidolite, Tremolite, Actinolite and Anthrophyllite from the Amphibole group (Sen, 2015). All six types are seen in different colors in hand specimen (Figure 2.1).

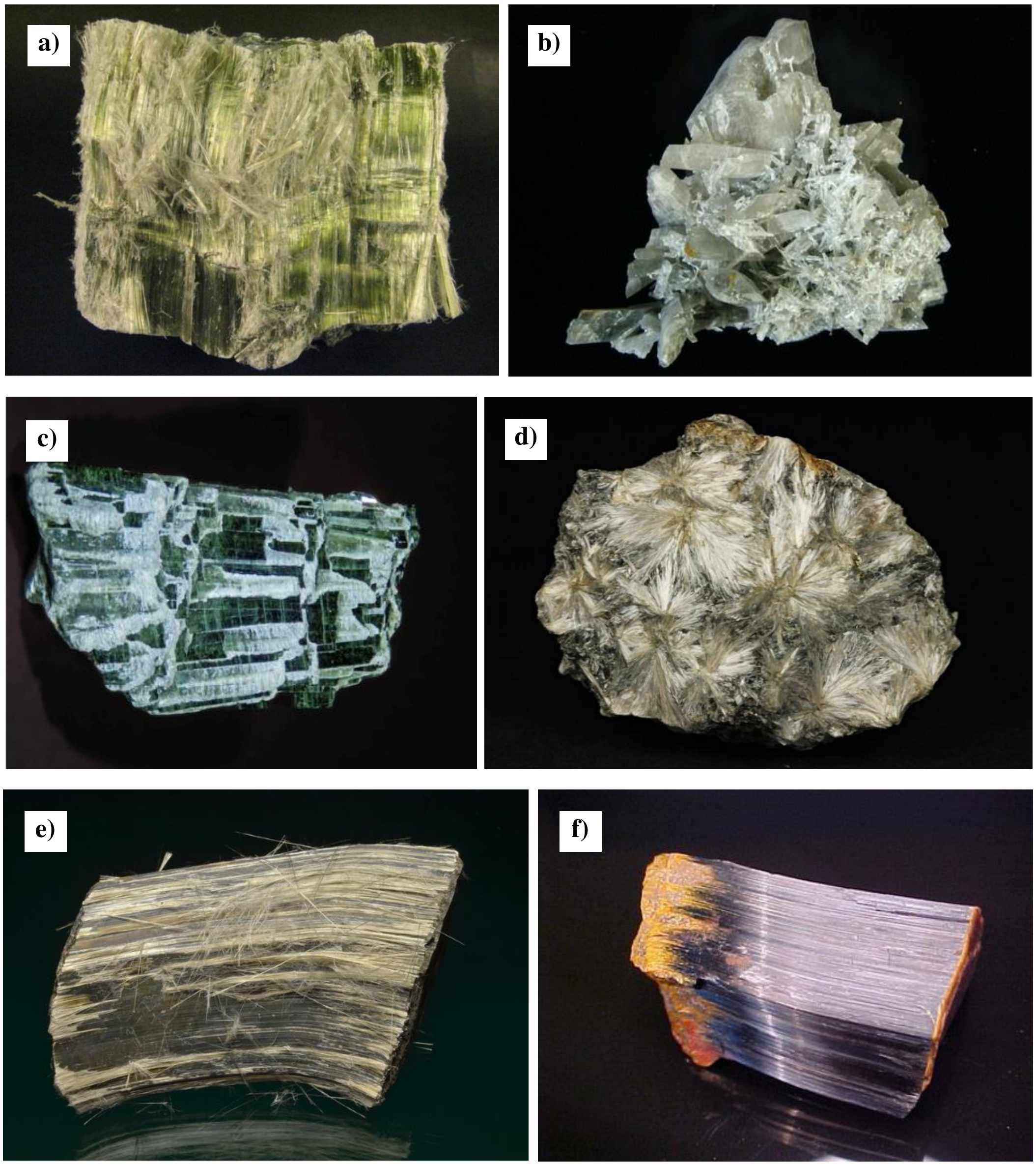


Figure 2.1. Types of asbestos minerals; a) Chrysotile, b) Tremolite, c) Actinolite, d) Anthophyllite, e) Amosite, f) Crocidolite (URL-3).

The asbestos minerals naturally occur due to regional metamorphism, contact metamorphism or magmatic hydrothermal alteration. If there are effects of fracturing, faulting and shearing providing conduits for hydrothermal fluid flow in an ultramafic body, asbestiform mineral formation occurs. Under the control of heat, pressure and fluid flow during regional metamorphism, Chrysotile, Anthophyllite, Tremolite and Actinolite are formed. If the fluid is iron-rich, the geological process results in Amosite and Crocidolite formation (Van Gosen, 2007).

The name used in the beginning, *a-sbestos*, refers to “incombustible” in Greek. Later on, the term asbestos was used collectively for Chrysotile, Amosite, Crocidolite, Tremolite, Actinolite and Anthrophyllite. Moreover, a sample called asbestos can be composed of one or more minerals. The chemical and physical properties are different from each other, but their aspect ratios (thickness: length) are at least 1:3 as a common property (Skinner *et al.*, 1988).

Commercially, some asbestos types are also known by different names around the globe. These are;

- white asbestos for Chrysotile,
- brown asbestos for Amosite, and
- blue asbestos for Crocidolite.

The minerals listed above are commonly used either as single or as mixture in the industry. On the other hand, the rest of asbestos types are too low in amount compared to white, brown and blue asbestos (Clinkenbeard *et al.*, 2002). The use of white asbestos, Chrysotile of serpentine group, as a construction material in buildings were preferred over other asbestos types due to its superior insulation properties (WHO, 2014).

2.3. Health Effects of Asbestos

When the asbestos exposure is examined, the studies conducted around the globe can be grouped under two main headings. Firstly, “environmental exposure” studies investigate people’s exposure to asbestos minerals from where they were born and / or where they live. It was found that asbestos exposure merely as a result of the environment in which people lived, regardless of the location of their workplace, caused serious health problems at a young age. An investigation on 379 villages of Turkey was conducted regarding the correlation between soil samples and cases of pulmonary cancer of local people. When the results and the cases were evaluated together, a critical connection was defined between asbestos content in soil and pulmonary cancer by the authors. In Turkey, planning towards controlling environmental exposure began in 2012 (Metintaş *et al.*, 2017).

The second heading of exposure source is the “occupational exposure”, in which people are personally affected by the asbestos extraction, production and processing. Most of the research in this area is related to worker health in industry branches which work directly with asbestos minerals such as mining, manufacturing and textile (Selinus and Alloway, 2005). According to WHO's 2014 world estimates, at least 107,000 people die each year from lung diseases such as mesothelioma, lung cancer or asbestosis caused by occupational exposure to asbestos. In fact, approximately 400 deaths are recorded annually from environmental asbestos exposure.

In 2003, asbestos was identified by the World Health Organization (WHO) and the International Labor Organization (ILO) as one of the most important occupational carcinogens. Pulmonary diseases and cancers were seen after exposure for at least 15 years (WHO, 2014). This period is critical in terms of living and working environments of the individuals.

Human epidemiology of disease increased from exposure to asbestos minerals. The observed diseases are: benign pleural disease (plaques, diffuse pleural thickening, and calcification), pulmonary fibrosis, lung cancers and mesothelioma of the pleura and peritoneum (Bildirici *et al.*, 2004). In Figure 2.2, tremolite and crysotile fibres detected in lung tissues are shown.

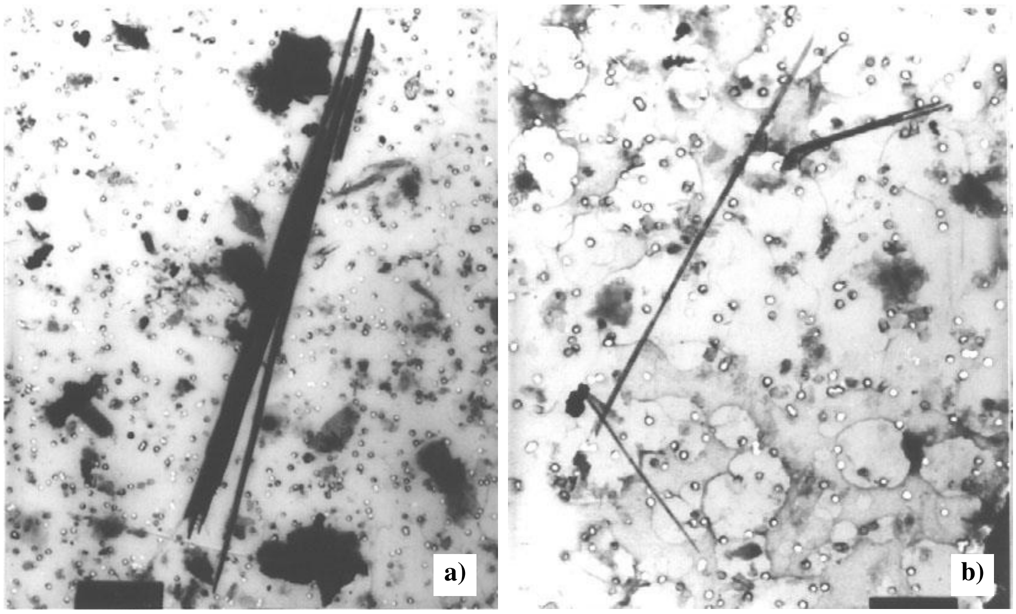


Figure 2.2. Electron micrographs of fibres detected in pleura a) tremolite, b) chrysotile (Bildirici *et al.*, 2004)

It is known that members of amphibole asbestos are more toxic than the serpentine group because of the amphiboles groups' greater longevity. Nevertheless, chrysotile was shown to cause tumors in animal studies. As a consequence, it was emphasized that toxicities of both chrysotile and the minerals of amphibole group are similar (Nishimura and Broaddus, 1998).

İn the following studies, health effect of Chrysotile was discussed in general. In the middle of 2000's, it was kwown that Chrysotile could present little/no carcinogenic risk if it is in pure form, and not in mixture with any other types of asbestos (Bartrip, 2004). On the other hand, Scherpereel *et al.* (2010) indicated that "Chrysotile is less biopersistent in the lungs than amphiboles".

Even though the Chrysotile carcinogenic effects are still not clear, it is known for sure that all types of asbestos are hazardous for human health. Among other types, Amosite and Crocidolite are the most hazardous ones due to their iron content. Moreover, exposure to these asbestos types are likely to cause Mesothelioma (Ross and Nolan, 2003).

Mesothelioma, one of the most deadly disease related to asbestos, is observed in some rural regions of Turkey. The occurrence of deaths related to asbestos-contaminated soil mixture was examined by Metintaş *et al.* in 2002 as environmental exposure to asbestos study. The results of the study show that although environmental exposure may be lower in comparison occupational exposure, the total exposure may be higher due to the long-term exposure period.

2.4. Asbestos Risk Assessment

The risk assessment of asbestos integrates two main sections such as material and priority assessment (HSE, 2004). Table 2.1 demonstrates the content of the material assessment and condition of asbestos-containing materials (ACMs). The possibility of an individual damaging the materials, is considered by the priority assessment in Table 2.2.

The equation of asbestos risk assessment is given below:

$$\text{Risk assessment score for each ACM} = \text{Material assessment score for each ACM} + \text{Priority assessment score for each ACM}$$

Four different parameters are assessed in material assessment algorithm. These are product type, extent of damage, surface treatment and asbestos type. The parameters are scored 0 to 3, and only one value is selected for each parameter. In order to complete this section, all parameters should be gathered.

Table 2.1. *Material assessment algorithm (HSE, 2004)*

Sample variable	**Score**	**Examples of scores**
Product type (or debris from product)	1	Asbestos reinforced composites (plastics, resins, mastics, roofing felts, vinyl floor tiles, semi-rigid paints or decorative finishes, asbestos cement etc.)
	2	Asbestos insulating board, mill boards, other low-density insulation boards, asbestos textiles, gaskets, ropes and woven textiles, asbestos paper and felt
	3	Thermal insulation (e.g. pipe and boiler lagging), sprayed asbestos, loose asbestos, asbestos mattresses and packing
Extent of damage / deterioration	0	Good condition: no visible damage
	1	Low damage: a few scratches or surface marks; broken edges on boards, tiles etc.
	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres
	3	High damage or delamination of materials, sprays and thermal insulation. Visible asbestos debris
Surface treatment	0	Composite materials containing asbestos: reinforced plastics, resins, vinyl tiles
	1	Enclosed sprays and lagging, asbestos insulating board (with exposed face painted or encapsulated), asbestos cement sheets etc.
	2	Unsealed asbestos insulating board, or encapsulated lagging and sprays
	3	Unsealed laggings and sprays
Asbestos type	1	Chrysotile
	2	Amphibole asbestos excluding crocidolite
	3	Crocidolite

Each of the parameters is scored in Table 2.1 and the material assessment score would be between 2 and 12 in the end. The scores signify the potential of releasing asbestos fibers. Scores of ≤4, 5-6, 7-9 and ≥10 correspond to very low, low, medium and high, respectively.

In Table 2.2, there are four different parameters that are divided into 2 or 3 parts. A difference according to material assessment, is that the average value of each parameter is gathered at the end of the assessment section.

Table 2.2. *Priority assessment algorithm (HSE, 2004)*

	Assessment factor	**Score**	**Examples of score variables**
Normal occupant activity	Main type of activity in area	0	Rare disturbance activity (e.g. little used store room)
		1	Periodic disturbance (e.g. industrial or vehicular activity which may contact ACMs)
		2	Low disturbance activities (e.g. office type activity)
		3	High levels of disturbance, (e.g. fire door with asbestos insulating board sheet in constant use)
	Secondary activities for area	As above	As above
Likelihood of disturbance	Location	0	Outdoors
		1	Large rooms or well-ventilated areas
		2	Rooms up to 100 m^2
		3	Confined spaces
	Accessibility	0	Usually inaccessible or unlikely to be disturbed
		1	Occasionally likely to be disturbed
		2	Easily disturbed
		3	Routinely disturbed
	Extent/amount	0	Small amounts or items (e.g. strings, gaskets)
		1	$\leq 10\ m^2$ or ≤ 10 m pipe run
		2	$>10\ m^2$ to $\leq 50\ m^2$ or >10 m to ≤ 50 m pipe run
		3	$>50\ m^2$ or >50 m pipe run
Human exposure potential	Number of occupants	0	None
		1	1 to 3
		2	4 to 10
		3	>10
	Frequency of use of area	0	Infrequent
		1	Monthly
		2	Weekly
		3	Daily
	Average time area is in use	0	<1 hour
		1	>1 to <3 hours
		2	>3 to <6 hours
		3	>6 hours
Maintenance activity	Type of maintenance activity	0	Minor disturbance (e.g. possibility of contact when gaining access)
		1	Low disturbance (e.g. changing light bulbs in asbestos insulating board ceiling)
		2	Medium disturbance (e.g. lifting one or two asbestos insulating board ceiling tiles to access a valve)
		3	High levels of disturbance (e.g. removing a number of asbestos insulating board ceiling tiles to replace a valve or for recabling)
	Frequency of maintenance activity	0	ACM unlikely to be disturbed for maintenance
		1	≤1 per year
		2	>1 per year
		3	>1 per month

After applying two assessments separately, the overall risk score is determined by combining the value of two assessments (Table 2.3).

Table 2.3. *Combined risk assessment (HSE, 2004)*

Category	**Overall risk score**	**Level of risk**	**Action**
Category A	18+	High risk	Immediate action
Category B	13-17	Medium risk	Near term action
Category C	9-12	Low risk	Regular inspection
Category D	8 or below	Very low risk	Annual inspection

Using this method of assessment is necessary to manage ACMs in the buildings before any repair or demolition process. Implementation of control measurements would succeed if ACMs identification and the risk assessment process are done (HSA, 2013).

CHAPTER 3

ASBESTOS CHARACTERIZATION IN CONSTRUCTION MATERIALS

This study consists of two main parts. After the specification of pilot regions, investigation studies are conducted according to the estimated existence of asbestos. Afterwards, risk rating concerning asbestos assessment and using the right methods for collecting samples are conducted. Thus far, the first part of the study is set to be examinations done under laboratory conditions, and the other part is referred to as “field work”. The second main part is an essential step of confirming the estimations from the first part. Based on determination approach, samples are examined mineralogically in detail via microscopes in “laboratory work” part.

Due to a covenant with the authorized people in all selected public buildings, and to avoid notoriety of these selected public buildings, the actual names of the buildings are not disclosed in this study. Therefore, in the rest of the thesis, the chosen 5 main regions are called Building-A, Building-B, Building-C, Building-D, Building-E.

After bureaucratic permissions, the pilot buildings are determined in October 2018 for this study. Up until the evaluation of the results and writing of the thesis, four other steps that are listed with their respective time periods are as follows:

1. Investigation: November – December 2018
2. Sampling: March 2019
3. Stereo Microscope Analysis: May – June 2019
4. Polarized Light Microscope Analysis: August – October 2019

Investigation studies and sampling steps are conducted in the selected buildings with the guidance of the authorized person in each building. The details of this section of the study are further disclosed in Section 3.1.

After finishing the field work, the laboratory studies were started. Applied analytical methods, such as Stereo Microscope and Polarized Light Microscope, are explained in Section 3.2. Moreover, the results of the analyses are discussed in the related subsections.

3.1. Field Work

After the locations of the study were selected, necessary permissions were obtained from authorized persons, in order to examine the buildings. Confidentiality is the most important aspect of this part of the study, because of the avoiding worry of the employees for asbestos topic. Dates, periods, and locations of the study are specified carefully in order to keep away from employees in each pilot buildings as far as possible.

The selected buildings are public buildings in which many people work. When deciding the pilot regions, the construction date is restricted to be between 1960 and 1980. Specifically, problematic constructions with clay grounds are selected. Moreover, the buildings which underwent frequently recondition were prioritized.

For this thesis, in 5 main regions, a total of 10 buildings and 32 floors were studied in Ankara. The 32 floors involve offices and the basement floors, but the roof is not examined due to safety purposes. Additionally, there are no attic floors on any of the buildings.

3.1.1. Investigation Studies

The investigation part includes examining both inside and outside of the buildings, taking photos of any questionable regions, and taking notes on the sketch of the floors, which are used in decision of the sampling points.

Both inside offices and the outside of the building are examined in detail for any crack formation. The renovation stories of the buildings are recorded and number of employees are noted. Because of the heating system has asbestos contained materials especially, the heat exchange stations and their pipelines were examined in detail.

The Building-A is a single building with two floors. The representative photographs of Building-A show any prior deformations and the present condition in Figure 3.1. The Building-B is a single building with three floors. The representative photographs of Building-B show deformations and present conditions in Figure 3.2. Building-C is a single building with four floors. The representative photographs of Building-C show deformations and present conditions in Figure 3.3. Building-D consists of four buildings with seventeen floors in total. The representative photographs of the Building-D show deformations and present conditions in Figure 3.4. The Building-E consists of three buildings with six floors in total. The representative photographs of the Building-E show deformations and present conditions in Figure 3.5.

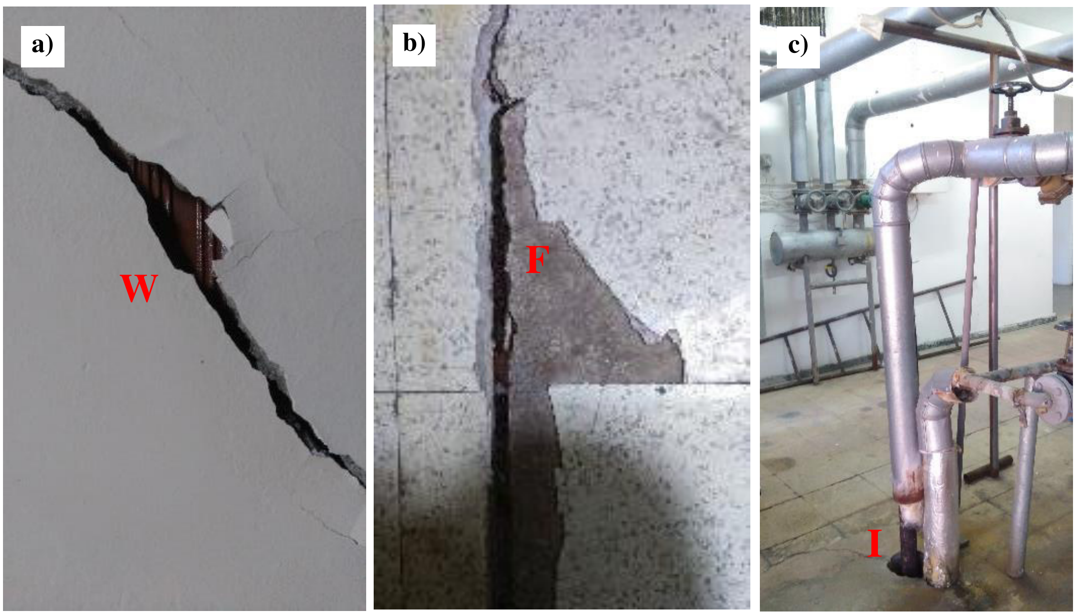


Figure 3.1. The Building-A's current conditions; a) wall (W), b) floor (F), c) insulation (I)

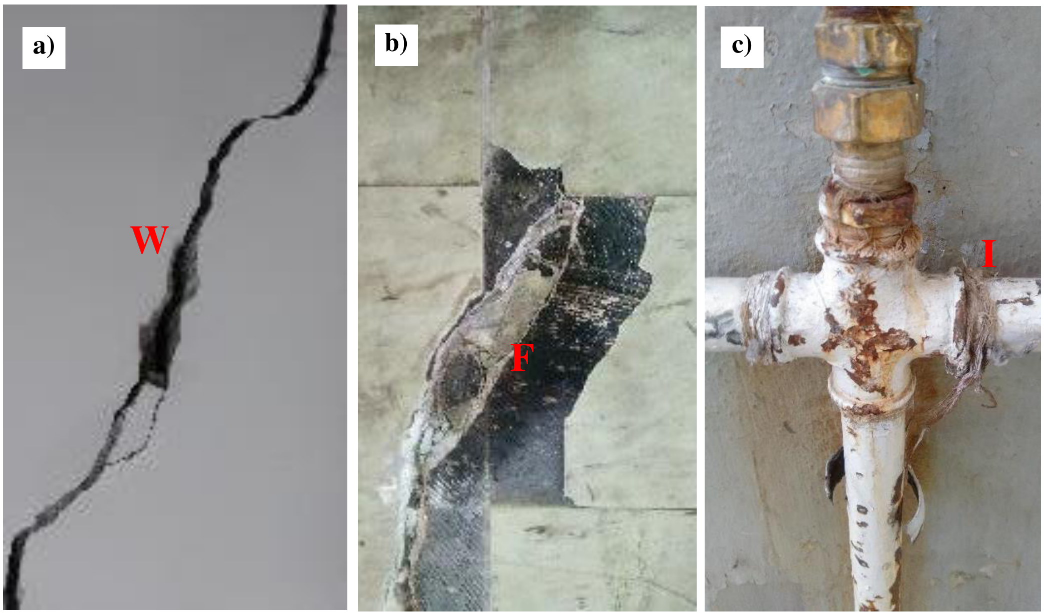


Figure 3.2. The Building-B's current conditions; a) wall (W), b) floor (F), c) insulation (I)

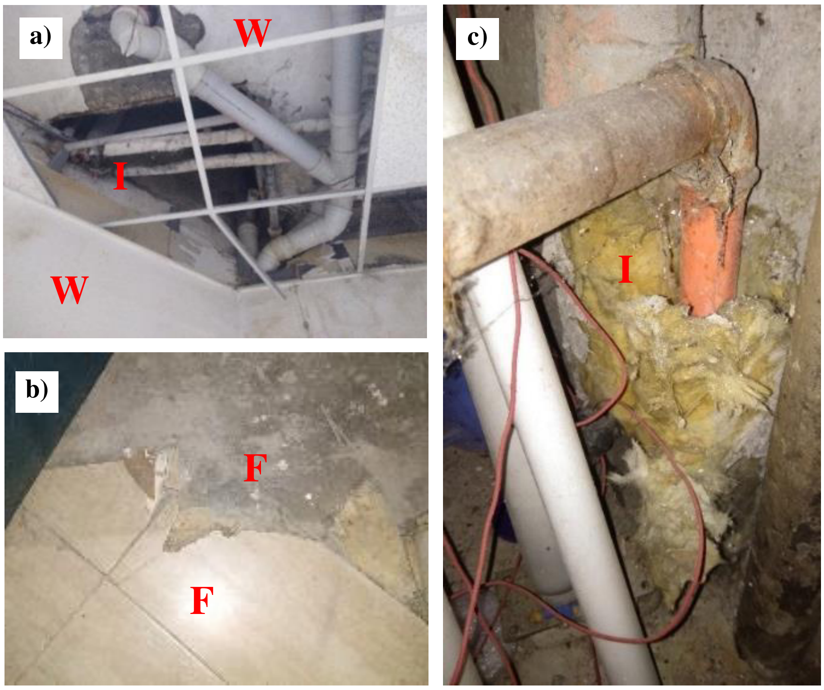


Figure 3.3. The Building-C's current conditions; a) wall (W) and insulation (I), b) floor (F), c) insulation (I)

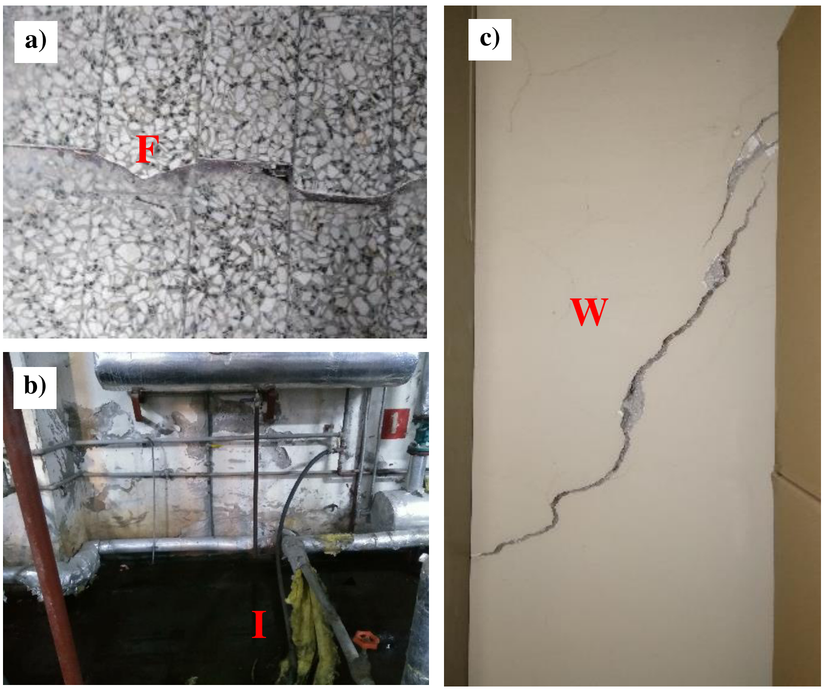


Figure 3.4. The Building-D's current conditions; a) floor (F), b) insulation (I), c) wall (W)

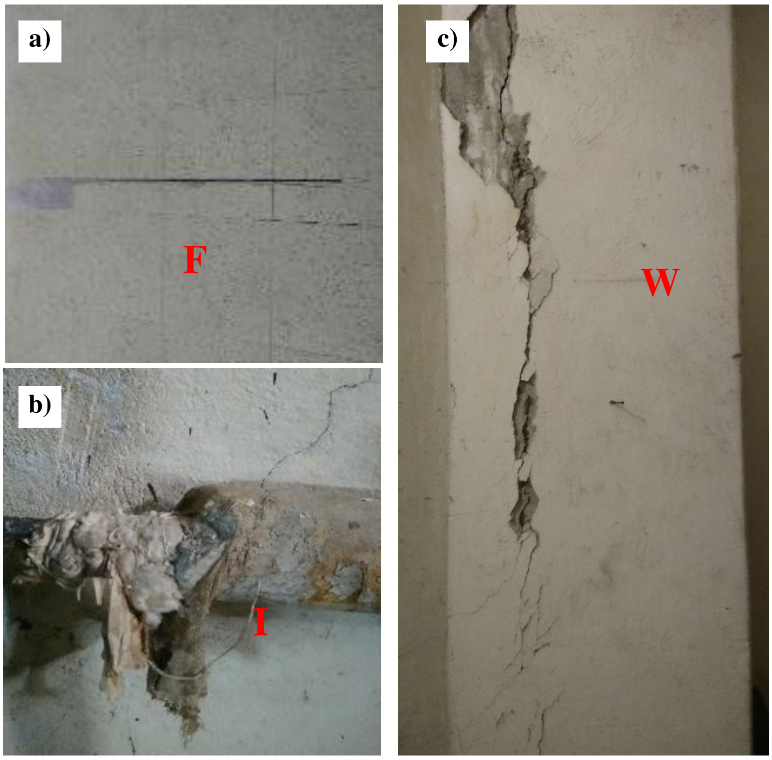


Figure 3.5. The Building-E's current conditions; a) floor (F), b) wall (W) & insulation (I), c) wall (W)

3.1.2. Risk Rating

When the risk rating is done in a region, it is very critical that the current condition of the materials and the potential of disturbance are evaluated together (Oberta, 2005). If there is no obvious condition at the releasing of fibers, predictions are applied for the risk rating process before the risk assessment.

Risk rating for the studied buildings is based on observations on the present conditions from the investigation studies. As explained in Section 3.1.1., the problematic areas are determined and noted in each of the floor sketches. Both materials conditions and frequency of use are necessary for the decision of the sample points, and the points are selected according to the risk rating approach.

3.1.3. Sampling

The deformed sections in the construction materials are selected for the sample collection step. All of the collected samples are bulk specimens and none of them are air samples. The ISO 22262 Standard requirements are used during sample collection.

The equipment shown in Figure 3.6 are used for taking samples from wall, floor and insulation materials. The samples are preserved in small sample bags and marked based on their location on the floor plan.

Figure 3.6. Sampling equipment; a) flat chinsel b) pointed chisel c) bent nose pliers d) hammer

One hundred and fifty samples of different dimensions were collected. The sample locations are grouped into three sections as being from either wall, floor or insulations. 52% of the samples is from walls, 25% is from floors, and 23% from insulations. The samples from walls, floors and insulations involve thirteen, nine and nine subtopics, respectively. The details of each material are given in Table 3.1.

Table 3.1. *Number and types with subtypes of the sampled materials*

Materials	Number	Details
WALL (77 samples)	19	Finishing coat
	17	Scratch coat
	8	Finishing coat + Wall paint
	4	Scratch coat + Wall paint
	2	Scratch/Finishing coat + Wall paint
	2	Scratch/Finishing coat
	6	Concrete
	6	Exposed concrete
	6	Brick
	1	Brick + Concrete
	2	Plasterboard
	2	Materials fragmented from main bodies
	2	Marble
FLOOR (38 samples)	19	Concrete tile
	7	Concrete
	3	Ceramic tile
	3	Vinyl floor covering
	2	Vinyl floor covering + Concrete
	1	VFC glue
	1	Epoxy
	1	Dust on the floor
	1	Textile based floor covering
INSULATION (35 samples)	15	Heat changer pipe insulation
	9	Pipe insulation
	3	Heat resistant rope
	2	Foamed sealant
	2	Melamine coated chipboard
	1	Dropped ceiling
	1	Insulating paper
	1	Vibration absorber
	1	Glass wool as insulation board filler

Whole samples are pounced and named separately in order to examine in the laboratory easily. Also, taking the photographs in hand specimen is done before powdering the samples. In this section of the thesis, the representative photographs are selected for different material types.

The sampled materials e.g. wall, floor, insulation, are sub grouped into two as predominating and rare ones, with the goal of summarizing their details in tables and photographs. The predominating construction materials are about 65% of wall, floor and insulation materials, separately.

i) Wall

52 samples out of 150 are predominately wall materials, and these are finishing coats and scratch coats with or without wall paints. The percentage of this set is 67.5% in all wall materials, and the details based on individual buildings are given in Table 3.2.

Table 3.2. *The samples of Finishing coat / Scratch coat materials*

A-02	scratch coat	**D-20**	scratch coat
A-03	finishing coat + wall paint	**D-22**	scratch coat
A-09	finishing coat + wall paint	**D-23**	finishing coat
A-10	scratch coat	**D-24**	scratch/finishing coat + wall paint
A-11	scratch/finishing coat + wall paint	**D-26**	finishing coat + wall paint
A-12	finishing coat	**D-33**	finishing coat
B-08	scratch coat + wall paint	**D-38**	scratch coat
B-09	scratch coat + wall paint	**D-40**	finishing coat
B-10	finishing coat	**D-41**	finishing coat
B-13	finishing coat	**D-42**	scratch coat
B-15	scratch coat + wall paint	**D-43**	finishing coat
C-04	finishing coat + wall paint	**E-01**	finishing coat
C-08	finishing coat + wall paint	**E-05**	finishing coat
C-11	scratch coat	**E-06**	finishing coat
C-15	finishing coat + wall paint	**E-08**	finishing coat
C-23	finishing coat + wall paint	**E-09**	scratch coat
D-02	scratch coat	**E-10**	scratch/finishing coat
D-03	scratch coat + wall paint	**E-12**	finishing coat
D-04	finishing coat + wall paint	**E-15**	finishing coat
D-06	finishing coat	**E-16**	finishing coat
D-07	scratch coat	**E-21**	scratch coat
D-11	scratch coat	**E-22**	scratch coat
D-12	scratch coat	**E-35**	scratch coat
D-14	scratch/finishing coat	**E-36**	finishing coat
D-15	finishing coat	**E-38**	scratch coat
D-16	scratch coat	**E-42**	finishing coat

The photographs of finishing coat + wall paint and scratch coat are given respectively in Figure 3.7, whereas representatives of the samples are presented in Table 3.2.

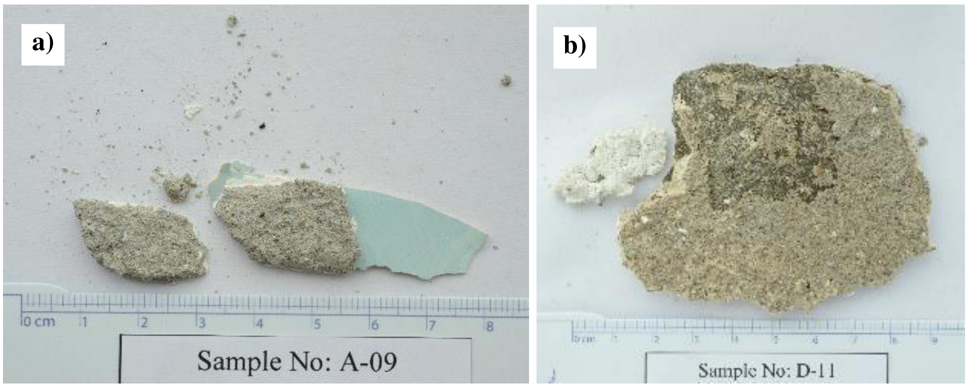


Figure 3.7. Representative macro-photographs of wall materials; a) finishing coat + wall paint, b) scratch coat

The number of the resting wall materials are 25 samples in total. These are concrete, brick, marble and plasterboard. This set is 32.5% whole wall materials, and the details based on individual buildings are given in Table 3.3.

Table 3.3. *Samples of Concrete / Brick / Marble / Plasterboard materials from the buildings*

A-05	concrete	**D-17**	concrete
B-07	exposed concrete	**D-18**	brick
B-11	brick	**D-19**	materials fragmented from main bodies
B-12	concrete	**D-21**	brick
B-14	exposed concrete	**D-39**	brick + concrete
C-05	exposed concrete	**E-02**	exposed concrete
C-07	brick	**E-04**	marble
C-09	concrete	**E-07**	concrete
C-10	brick	**E-17**	concrete
C-12	materials fragmented from main bodies	**E-18**	plasterboard
C-14	plasterboard	**E-37**	exposed concrete
D-01	brick	**E-41**	exposed concrete
D-05	marble		

The photographs of brick, concrete, exposed concrete, plasterboard, marble and materials fragmented from main bodies are conveyed in Figure 3.8 in said order, whereas the representatives are given in Table 3.3.

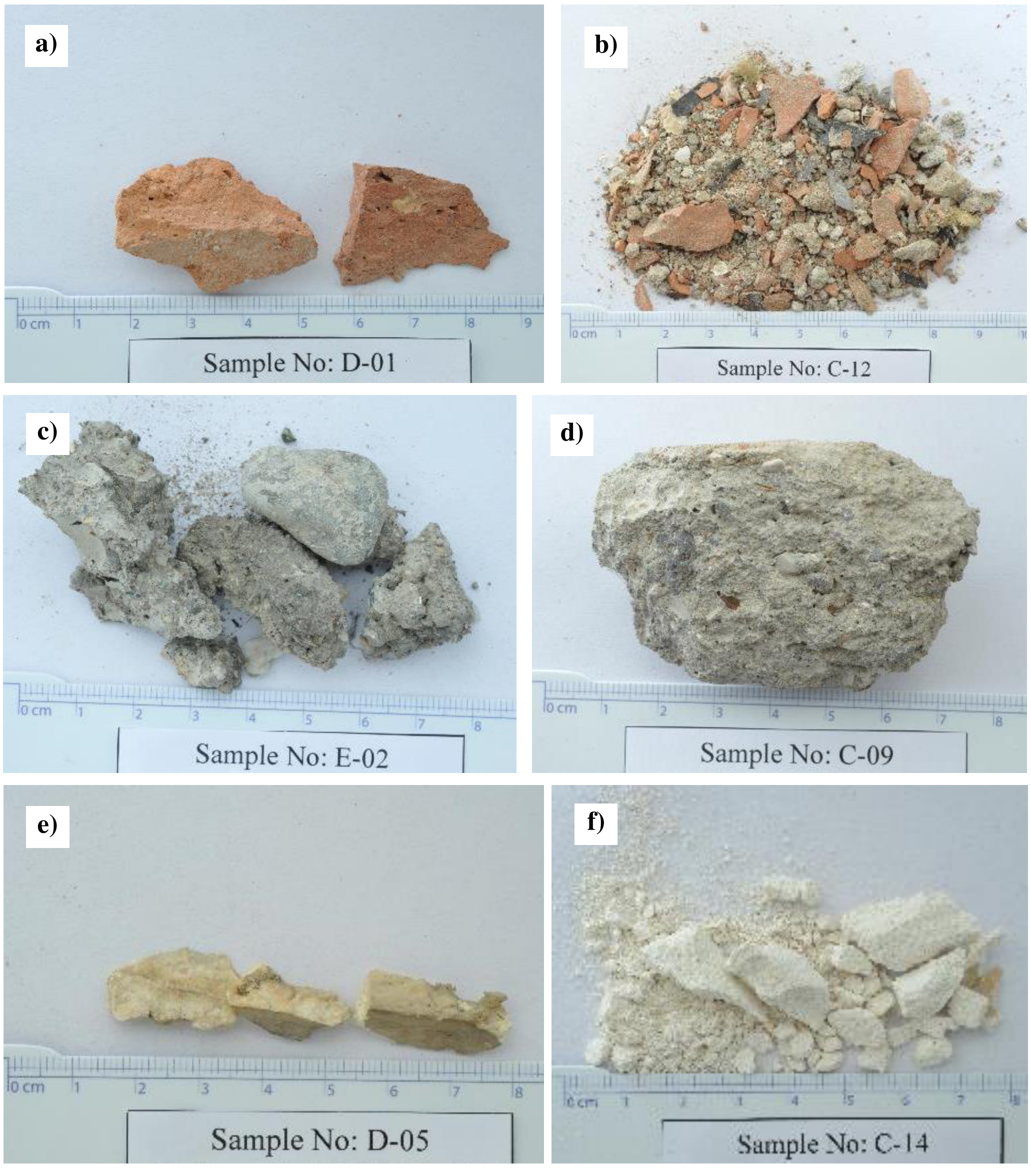


Figure 3.8. Representative macro-photographs of wall materials; a) brick, b) materials fragmented from the main bodies, c) exposed concrete, d) concrete, e) marble, f) plasterboard

ii) Floor

26 samples are from the floor materials that are either concrete or concrete tile. This set is 68.4% whole floor materials, details based on each building are demonstrated in Table 3.4.

Table 3.4. *Samples of Concrete / Concrete tile materials*

A-01	concrete	**D-09**	concrete tile
A-06	concrete tile	**D-10**	concrete tile
A-13	concrete tile	**D-25**	concrete
A-14	concrete	**D-34**	concrete tile
A-16	concrete tile	**E-03**	concrete tile
A-17	concrete tile	**E-13**	concrete
B-01	concrete	**E-14**	concrete tile
B-03	concrete tile	**E-20**	concrete tile
B-04	concrete tile	**E-24**	concrete
B-06	concrete tile	**E-25**	concrete tile
B-16	concrete tile	**E-32**	concrete
C-02	concrete tile	**E-43**	concrete tile
D-08	concrete tile	**E-45**	concrete tile

The macro-photographs of concrete and concrete tiles are given in Figure 3.9 in the same order, whereas representatives of the samples are given in Table 3.4.

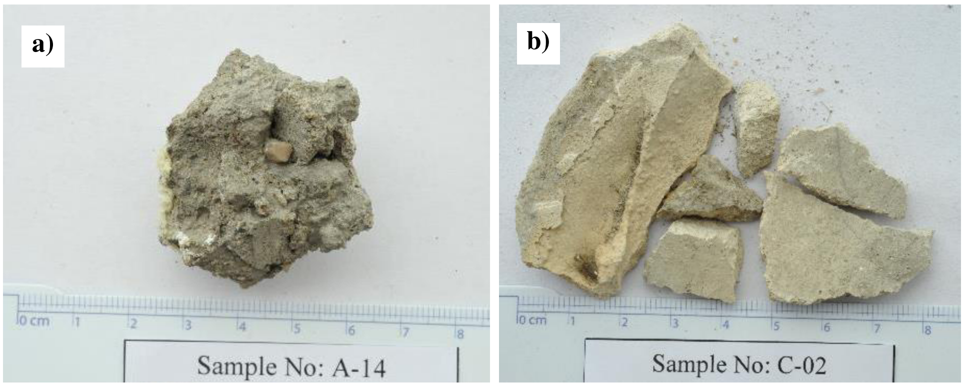


Figure 3.9. Representative macro-photographs of the floor materials; a) concrete, b) concrete tile

The number for rest of the floor material samples is 12. These samples are VFC (Vinyl Floor Covering), ceramic tile, epoxy and textile-based floor covering. This set is 31.6% in whole floor materials, and the details on buildings are given in Table 3.5.

Table 3.5. *The samples of VFC / Ceramic tile / Epoxy / Textile based floor covering materials*

A-07	vinyl floor covering + concrete	**C-01**	ceramic tile
A-15	vinyl floor covering	**D-13**	ceramic tile
A-18	VFC glue	**E-11**	epoxy
A-20	ceramic tile	**E-23**	vinyl floor covering
A-22	dust on the floor	**E-33**	vinyl floor covering
B-02	vinyl floor covering + concrete	**E-34**	textile based floor covering

The macro-photographs of ceramic tile, VFC, epoxy and textile based floor covering are given in Figure 3.10 respectively, whereas representatives of the samples are given in Table 3.5.

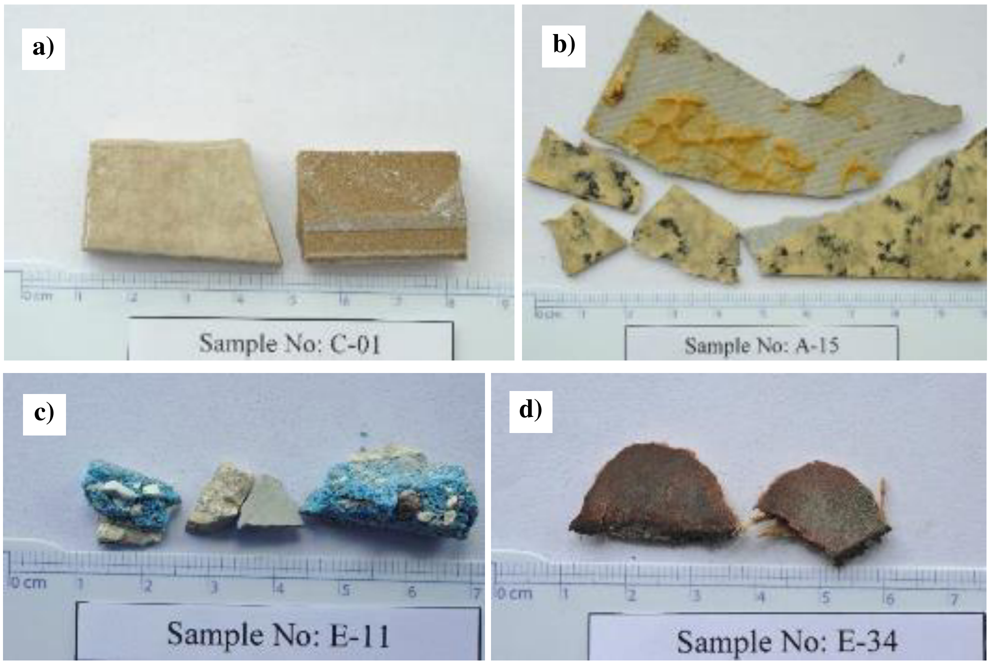


Figure 3.10. Representative macro-photographs of floor materials; a) ceramic tile, b) vinyl floor covering, c) epoxy, d) floor covering based textile

iii) Insulation

24 samples out of a total of 150 samples are the representative examples of insulation materials which are heat changer pipe insulation and pipe insulation. This set is 68.6% whole insulation materials, and the details on buildings are demonstrated in Table 3.6.

Table 3.6. *The Samples of Heat changer pipe insulation / Pipe insulation materials*

A-19	heat changer pipe insulation	**D-35**	heat changer pipe insulation
A-21	heat changer pipe insulation	**D-36**	heat changer pipe insulation
C-16	pipe insulation	**D-37**	heat changer pipe insulation
C-19	pipe insulation	**E-19**	pipe insulation
C-20	pipe insulation	**E-26**	heat changer pipe insulation
C-21	pipe insulation	**E-27**	heat changer pipe insulation
D-27	pipe insulation	**E-28**	heat changer pipe insulation
D-28	heat changer pipe insulation	**E-29**	heat changer pipe insulation
D-29	heat changer pipe insulation	**E-30**	heat changer pipe insulation
D-30	pipe insulation	**E-31**	heat changer pipe insulation
D-31	pipe insulation	**E-39**	heat changer pipe insulation
D-32	pipe insulation	**E-40**	heat changer pipe insulation

The macro-photographs of heat changer pipe insulation and pipe insulation are given accordingly in Figure 3.11, whereas representatives of the samples are bestowed in Table 3.6.

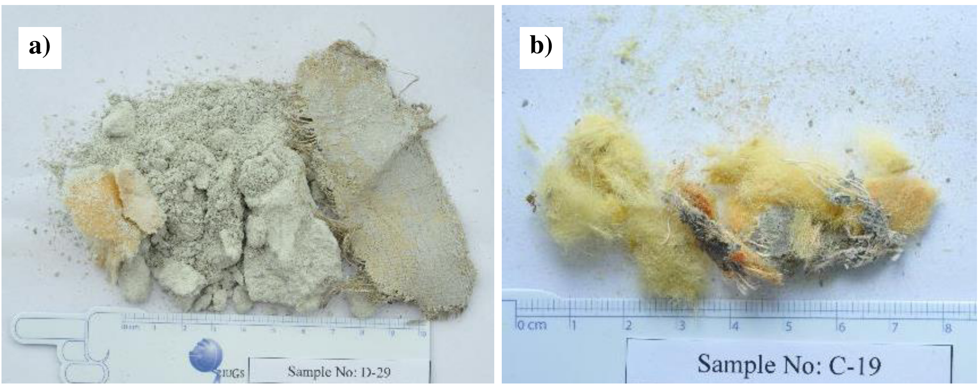


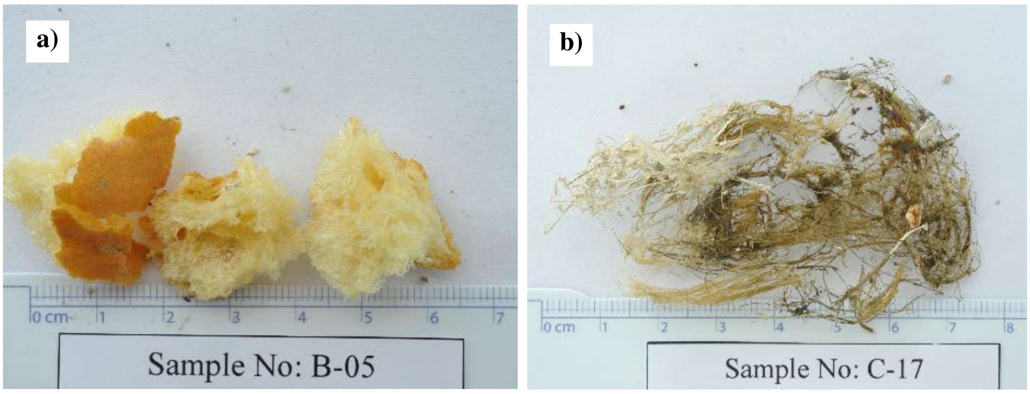
Figure 3.11. Representative macro-photographs of insulation materials; a) heat changer pipe insulation, b) pipe insulation

The number of the resting insulation materials are determined to be 11. These materials include foamed sealant, heat resistant rope, vibration absorber, insulating paper, dropped ceiling and melamine coated chipboard. This set is 31.4% whole insulation materials, and the details based on each building are presented in Table 3.7.

Table 3.7. *The samples of Foamed sealant / Vibration absorber / Heat resistant rope / Insulating paper / Dropped ceiling / Melamine coated chipboard materials*

A-04	foamed sealant	**C-13**	insulating paper
A-08	vibration absorber	**C-17**	heat resistant rope
B-05	foamed sealant	**C-18**	heat resistant rope
B-17	heat resistant rope	**C-22**	melamine coated chipboard ceiling cladding
C-03	dropped ceiling	**E-44**	melamine coated chipboard
C-06	insulation board filler glass wool		

The macro-photographs of foamed sealant, heat resistant rope, vibration absorber, insulating paper, dropped ceiling and melamine coated chipboard are shown correspondingly in Figure 3.12 whereas representatives of the samples are given in Table 3.7.



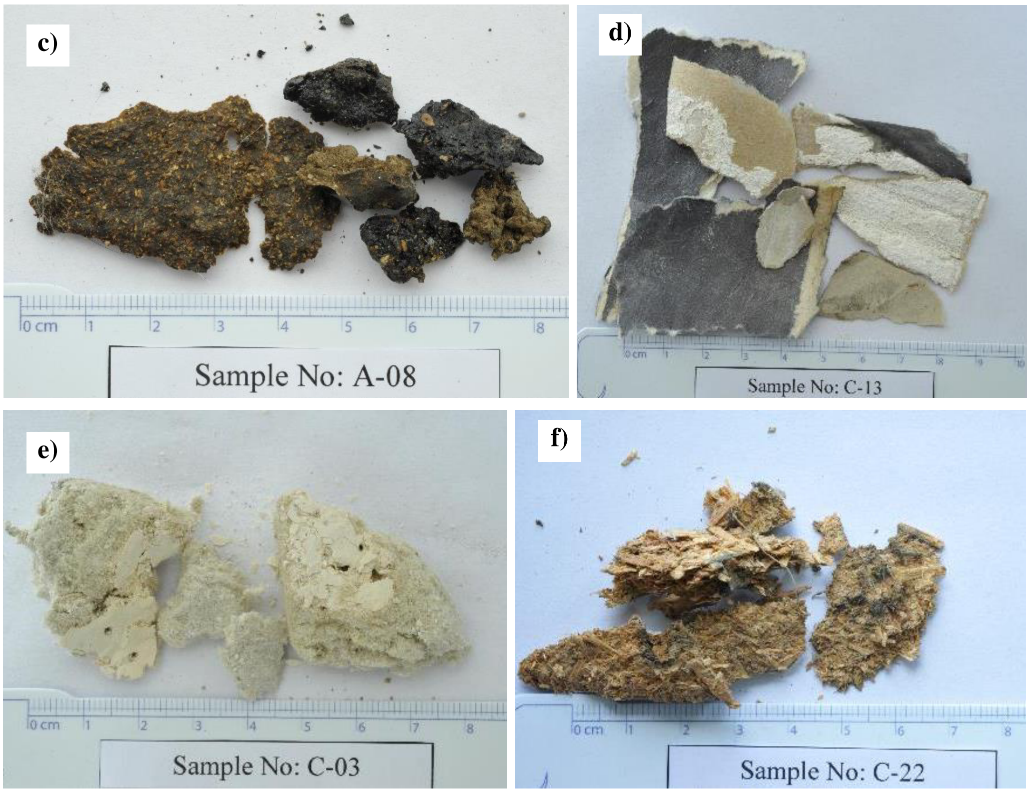


Figure 3.12. Representative macro-photographs of insulation materials; a) foamed sealant, b) heat resistant rope, c) vibration absorber, d) insulating paper, e) dropped ceiling, f) melamine coated chipboard

3.2. Laboratory Work

The collected samples are examined in the Laboratories of Department of Geological Engineering in METU to determine the existence of fibrous materials, as well as the amount and type of asbestos in these fibers. The microscopes that were used in this reseach are shown in Figure 3.13.

The fibrous forms are detected by stereo microscopic analysis, and the samples are classified regarding concentration of the fibrous materials, as explained in Section 1.4. Then, petrographic analyses by polarized light microscope are applied on the samples. This method is essential for the identification of asbestos fibers within the bulk samples of the construction materials.

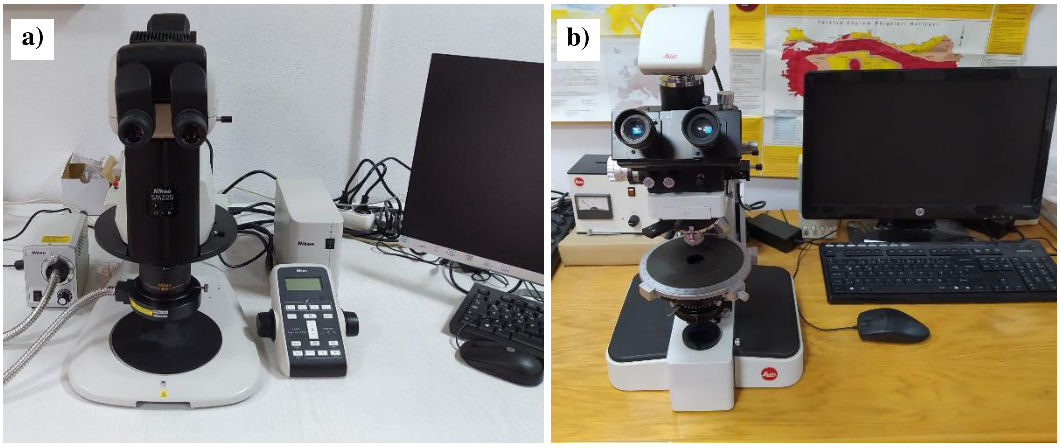


Figure 3.13. Microscopes used; a) Stereo Microscope, b) Polarized Light Microscope

3.2.1. Stereo Microscopic Analysis

The study by stereo microscope in this thesis aims to find out the fibrous forms in the samples. Whole samples are examined and grouped into five classes as shown in Table 1.1. According to this classification, the number of the samples without any fibrous content is 27; on the other hand, the rest of the collected 150 samples have fibrous material: The samples with fibrous form are divided into four groups based on density of the fibrous form. The percentage of the samples with the most intense fibrous material is 24.7 (37 samples) of the total samples. The percentages from the second degree of intensity and the third degree are 6.0%, 19.3%, respectively.

Distribution of the 150 construction samples from wall, floor and insulation within the intensity-based classification with five groups, are summarized in Table 3.8. The percentages and numbers in the Table are evaluated for wall, floor and insulation, separately.

Table 3.8. *The numbers and percentages of the classified samples based on intensity of fibrous content*

	Wall		Floor		Insulation	
	#	%	#	%	#	%
✕	22	***28.5***	5	***13.2***	0	***0.0***
✓	38	***49.4***	9	***23.7***	1	***2.9***
✓✓	14	***18.2***	13	***34.2***	2	***5.6***
✓✓✓	1	***1.3***	7	***18.4***	1	***2.9***
✓✓✓✓	2	***2.6***	4	***10.5***	31	***88.6***

In samples denoted with a cross symbol, there is no insulation material. That being said, other classes include all types of materials such as wall, floor and insulation in varying amounts. One of each exposed concrete and plasterboard for wall samples, also certain levels of each concrete, VFC and textile-based floor covering for floor samples have four check mark symbols. Representative micro-photographs for each material (Table 3.8) through a stereo microscope is given in Figure 3.14, Figure 3.15, Figure 3.16, Figure 3.17 and Figure 3.18, respectively.

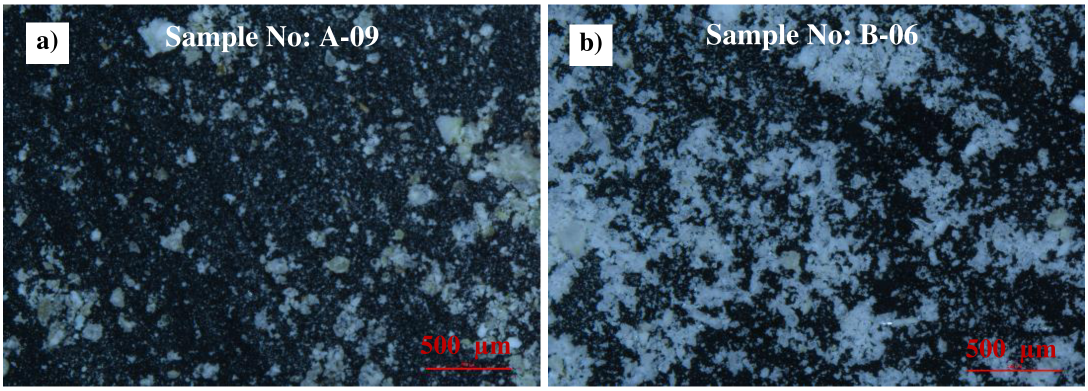


Figure 3.14. Representative micro-photographs by stereo microscope showing the samples without the fibrous form (marked by a cross mark in Table 3.8); a) Wall (finishing coat + wall paint), b) Floor (concrete tile)

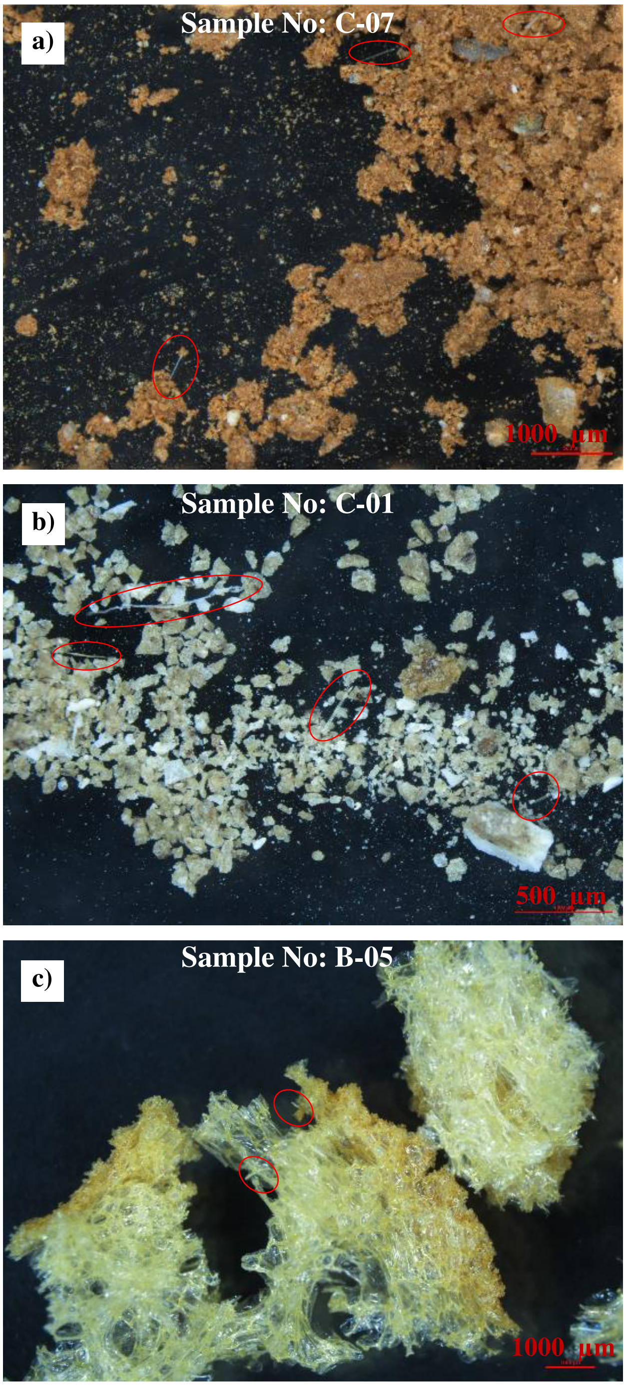


Figure 3.15. Representative micro-photographs by stereo microscope showing the samples with the fibrous form (marked by a check mark in Table 3.8); a) Wall (brick), b) Floor (ceramic tile), c) Insulation (foamed sealant) *[red circled area displays fibrous materials]*

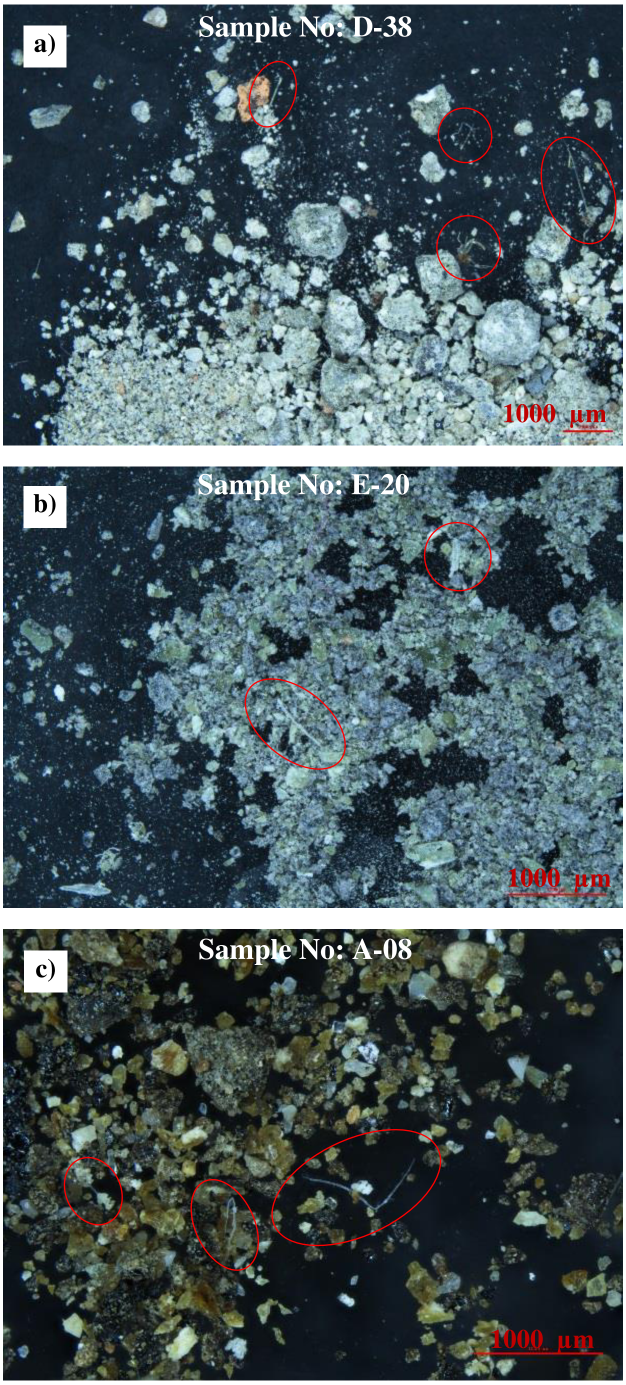


Figure 3.16. Representative micro-photographs by stereo microscope showing the samples with the fibrous form (marked by two check marks in Table 3.8); a) Wall (scratch coat), b) Floor (concrete tile), c) Insulation (vibration absorber) *[red circled area displays fibrous materials]*

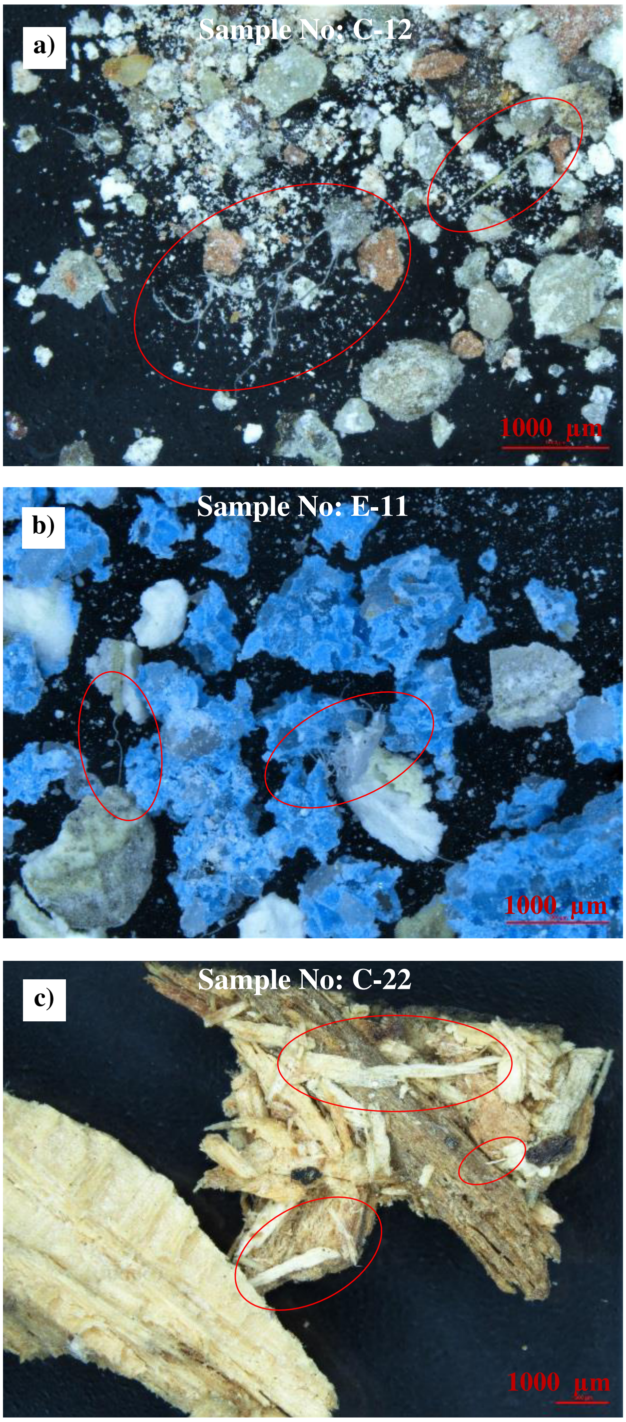


Figure 3.17. Representative micro-photographs by stereo microscope showing the samples with the fibrous form (marked by three check marks in Table 3.8); a) Wall (materials fragmented from main bodies), b) Floor (epoxy), c) Insulation (melamine coated chipboard ceiling cladding) *[red circled area displays fibrous materials]*

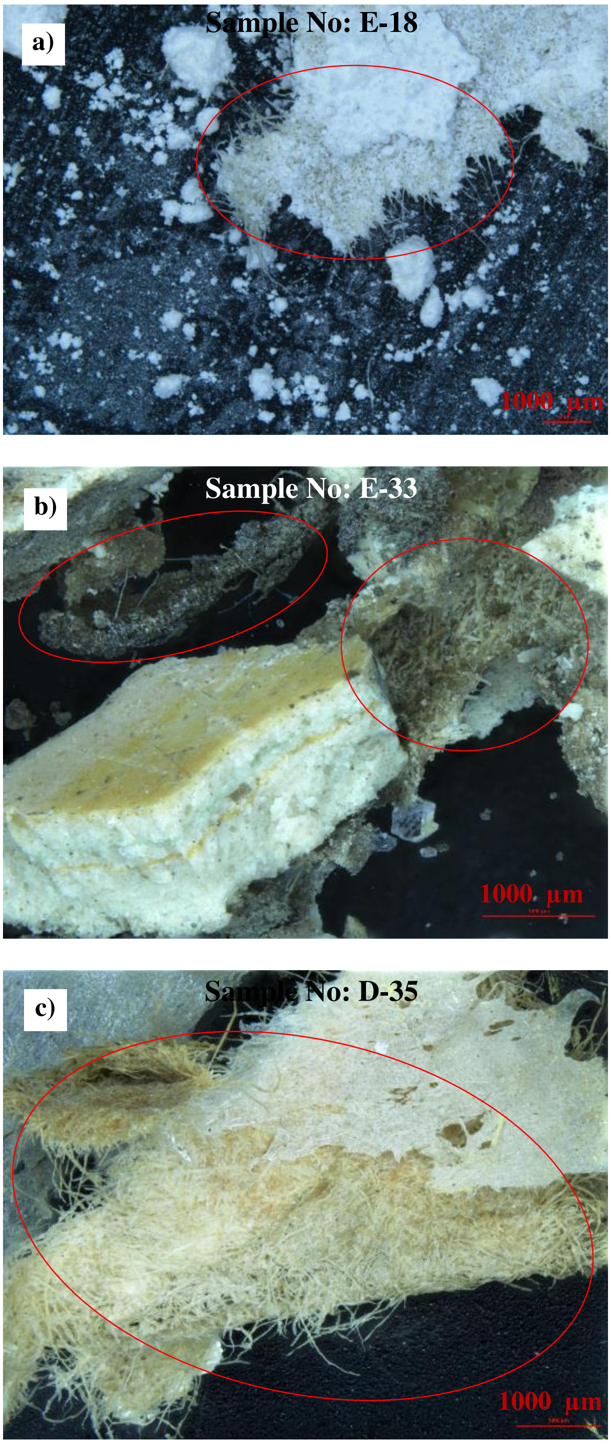


Figure 3.18. Representative micro-photographs by stereo microscope showing the samples with fibrous form (marked by four check in Table 3.8); a) Wall (plasterboard), b) Floor (vinyl floor covering), c) Insulation (heat exchanger pipe insulation) *[red circled area displays fibrous materials]*

Following this step, all of the samples were found unsuitable to examine under PLM, which are especially below two check marks; because they are evaluated to be safe. For this reason, 75 samples with two, three or four check marks and variably high intensity of fibrous materials are selected (Table 3.9) and examined under PLM.

Table 3.9. *Distribution of the density-based samples suitable for PLM examination*

	✓✓✓✓ (number)	✓✓✓ (number)	✓✓ (number)
Building-A	3	3	7
Building-B	1	0	3
Building-C	9	2	4
Building-D	9	1	5
Building-E	15	3	10
TOTAL	***37***	***9***	***29***

3.2.2. Polarized Light Microscopic Analysis

To examine under polarized light microscope, samples denoted with the cross and one check mark are not selected due to their trifling density, also considering that these do not pose a threat for health in terms of asbestos. Identification of asbestos type in dense samples is crucial for the high likelihood of affecting employees in the buildings.

Nearly half of those studied samples are materials with four check marks (Table 3.9). Moreover, the percentages of the examined samples are 59, 24, 65, 35 and 62 in Building-A, Building-B, Building-C, Building-D and Building-E, respectively. When these 75 samples are evaluated on a material basis rather than a construction basis, it is concluded that not all types of materials are examined in PLM because of the less density of fibrous structures. Similarly, some of the other material types are not studied due to the same reason.

i) Wall

Only 17 wall samples are examined under PLM, and details of the materials are shown in Table 3.10. Besides, the samples examined constitute 22% of all wall samples. The wall samples that have less density based on the created classification are denoted with "-" in Table 3.10. Also, in the column on density in the table include the density of both examined and unexamined samples. Table 3.11 and Table 3.12, show only the examined ones with their density classifications.

Table 3.10. *The number of the wall samples examined under PLM*

Material details	**Initial sample number**	**PLM examined sample number**	**Density of fibrous materials**
Finishing coat	19	3	✓✓
Scratch coat	17	4	✓✓
Finishing coat + Wall paint	8	2	✓✓
Scratch coat + Wall paint	4	-	✗
Scratch/Finishing coat + Wall paint	2	-	✓
Scratch/Finishing coat	2	-	✗ / ✓
Concrete	6	-	✗ / ✓
Exposed concrete	6	3	✓✓ / ✓✓✓✓
Brick	6	1	✓✓
Brick + Concrete	1	-	✓
Plasterboard	2	1	✓✓✓✓
Materials fragmented from main bodies	2	2	✓✓ / ✓✓✓
Marble	2	1	✓✓
TOTAL	***77***	***17***	

ii) Floor

24 number of floor samples are examined under PLM, and details of the materials are summarized in Table 3.11. Besides, the samples examined constitute 63 percent of all floor samples.

Table 3.11. *The numbers of the floor samples examined under PLM*

Material details	**Initial sample number**	**PLM examined sample number**	**Density of fibrous materials**
Concrete tile	19	9	✓✓ | ✓✓✓
Concrete	7	5	✓✓ | ✓✓✓ | ✓✓✓✓
Ceramic tile	3	1	✓✓
Vinyl floor covering	3	3	✓✓ | ✓✓✓ | ✓✓✓✓
Vinyl floor covering + Concrete	2	2	✓✓
VFC glue	1	1	✓✓✓
Epoxy	1	1	✓✓✓
Dust on the floor	1	1	✓✓✓
Textile based floor covering	1	1	✓✓✓✓
TOTAL	***38***	***24***	

iii) Insulation

34 of the total 35 insulation samples are examined under PLM, and the details of the materials are displayed in Table 3.12. In other words, 97% of the insulation samples constitute of fibrous materials in order to be properly examined by PLM.

Table 3.12. *The numbers of the insulation samples examined under PLM*

Material details	**Initial sample number**	**PLM examined sample number**	**Density of fibrous materials**
Heat changer pipe insulation	15	15	✓✓✓✓
Pipe insulation	9	9	✓✓✓✓
Heat resistant rope	3	3	✓✓✓✓
Foamed sealant	2	1	✓✓
Melamine coated chipboard	2	2	✓✓✓ | ✓✓✓✓
Dropped ceiling	1	1	✓✓✓✓
Insulating paper	1	1	✓✓✓✓
Vibration absorber	1	1	✓✓
Insulation board filler glass wool	1	1	✓✓✓✓
TOTAL	***35***	***34***	

The study under PLM is conducted with micro-photographs to record and identify the sample classification. This part is conducted on the samples with four check marks

(✓✓✓✓) by taking 125 micro-photographs, the samples with three check marks (✓✓✓) by taking 33 micro-photographs, and the samples with two check marks (✓✓✓) by taking 47 micro-photographs. The total number of microscopic photographs is 205. This means that approximately an average of 2.9 micro-photographs are recorded for each of the 75 samples studied under PLM.

The analysis by PLM is conducted with the specific refractive index oil which allows to define RI of the asbestiform fibrous materials as well as other optical properties. Becke Line Test is applied at analyzer-out position, and also color and pleochroism are examined using the same light. Furthermore, birefringence, extinction and sign of elongation for the fibrous forms are defined at an analyzer-in position. All observations are used to specify asbestos types with accordance to Table 1.3. In the 5 samples out of a total of 75 samples were examined by PLM, asbestos minerals were not detected despite the existence of the fibrous (asbestiform) materials. The samples that are free of asbestos are categorized in the class denoted by two check marks (Table 3.13). The fibrous materials are that of glass wool used for insulation.

Table 3.13. *The samples with fibrous material but which are not asbestos*

Building	**Sample no**	**Material type**	**Detail**
Building-C	C-08	Wall	finishing coat + wall paint
Building-E	E-04	Wall	marble
	E-25	Floor	concrete tile
	E-35	Wall	scratch coat
	E-38	Wall	scratch coat

Micro-photographs of all samples were taken both at analyzer-out and analyzer-in positions. The representative micro-photographs of wall, floor and insulation classes are displayed in Figure 3.19, Figure 3.20 and Figure 3.21. In these figures, views of the same sample in interest both at analyzer out and in positions are given. Analyzer-in positions are expressed with apostrophe sign on the microphotographs. The fibrous materials with different birefringence color indicate the existence of asbestos minerals in the sample.

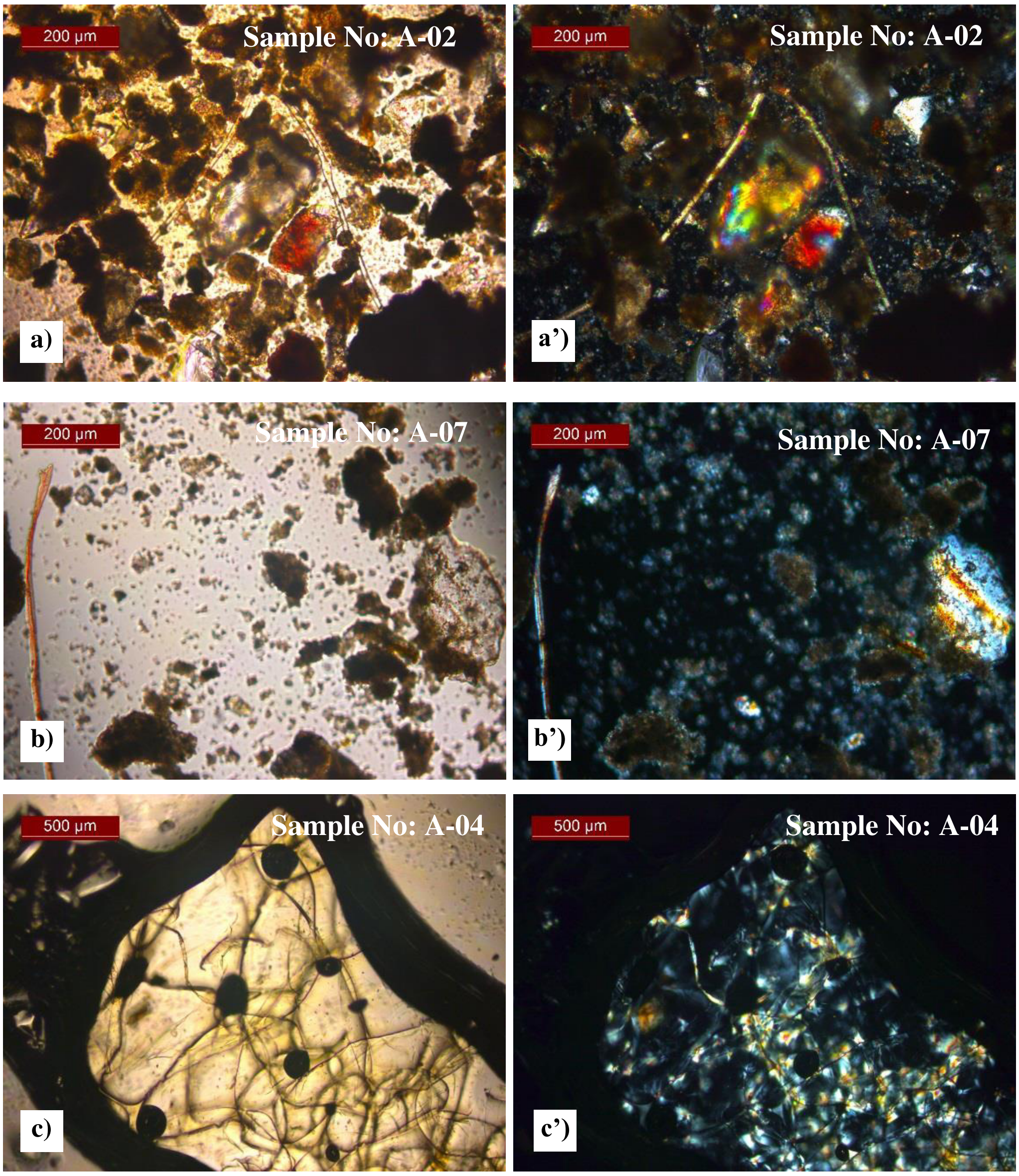


Figure 3.19. Representative micro-photographs of the samples with two check marks under PLM; a) Wall (scratch coat), b) Floor (vinly floor covering), c) Insulation (foamed sealant) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

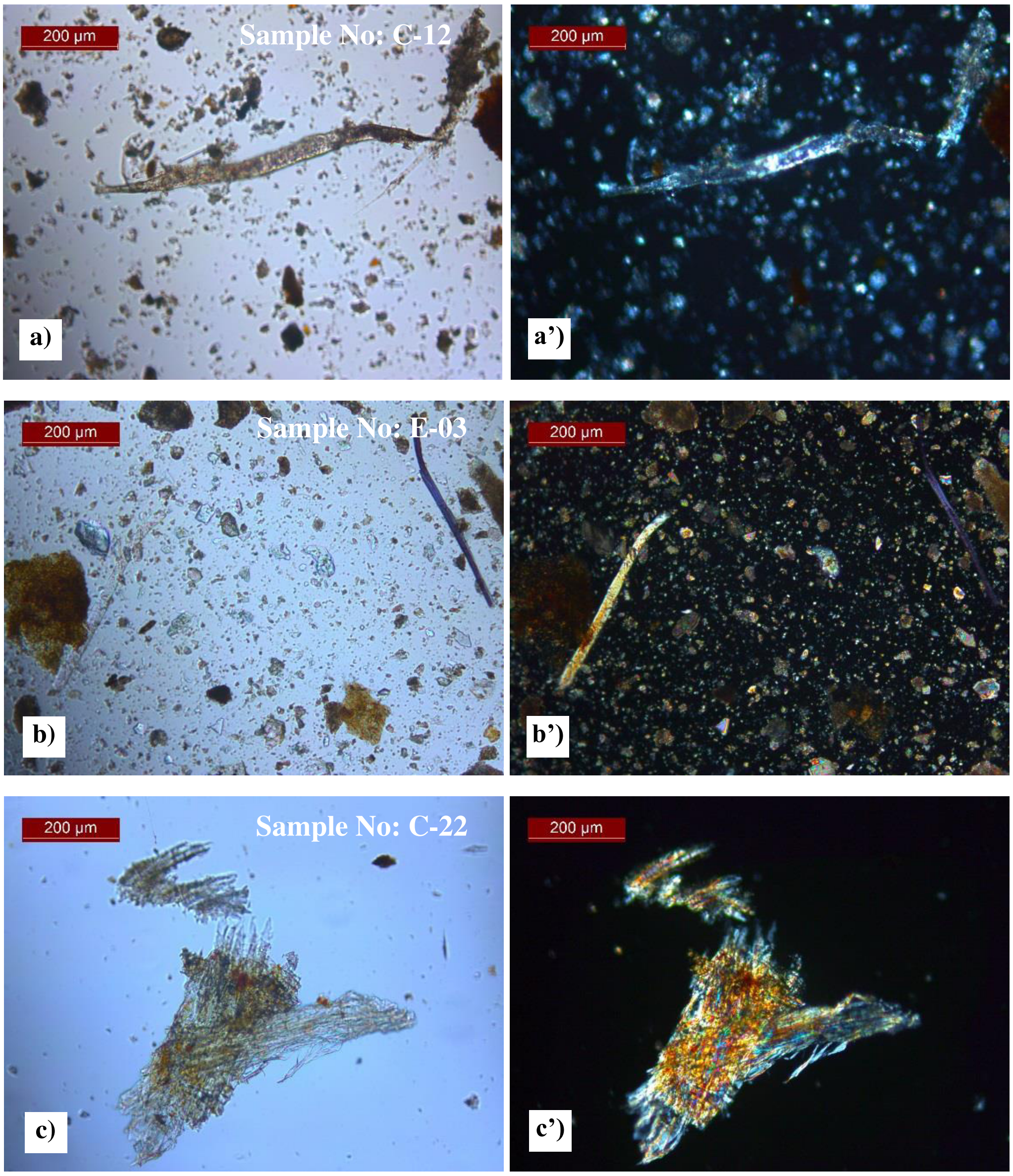


Figure 3.20. Representative micro-photographs of the samples with three check marks under PLM; a) Wall (materials fragmented from main bodies), b) Floor (concrete tile), c) Insulation (melamine coated chipboard ceiling cladding) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

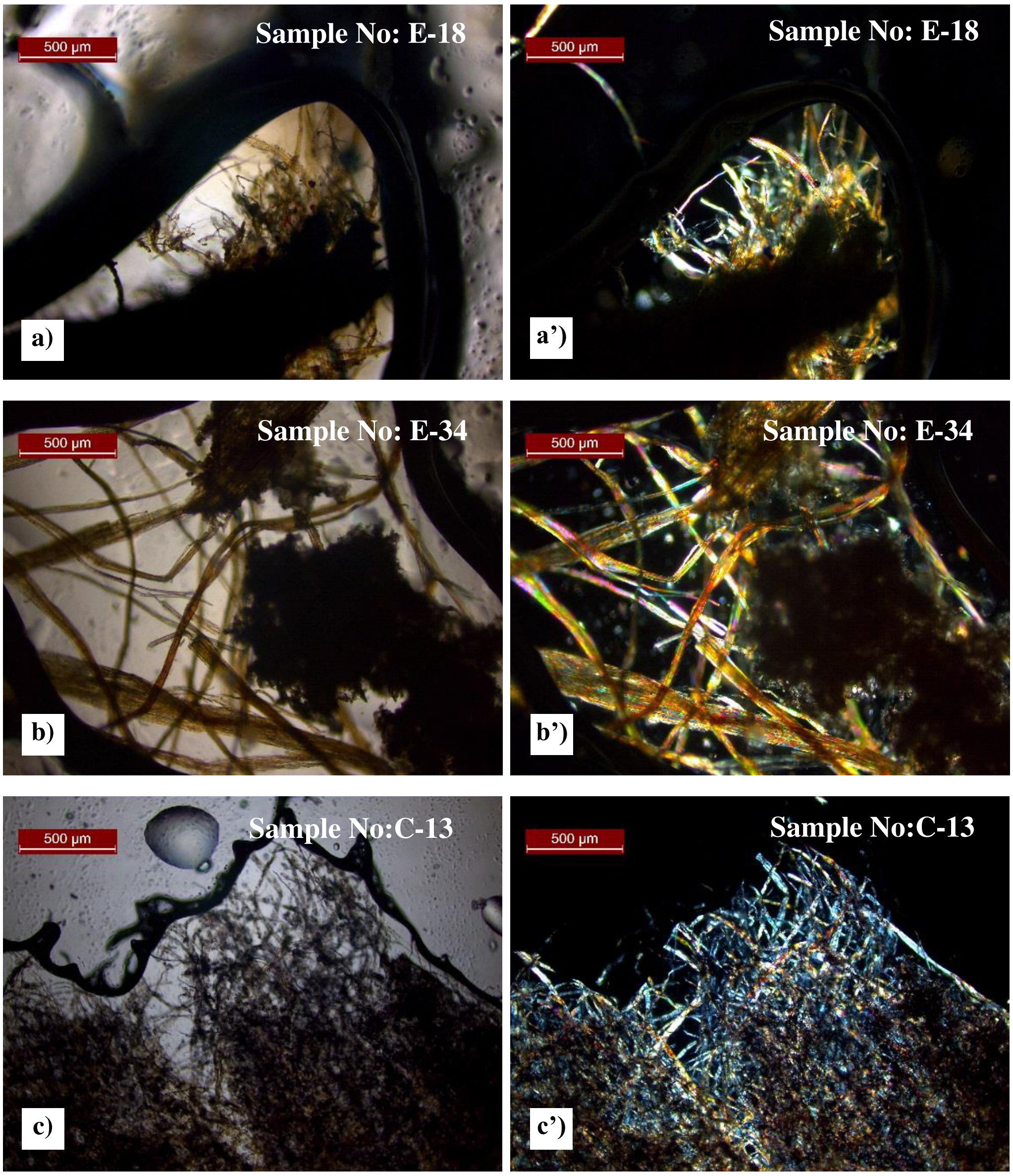


Figure 3.21. Representative micro-photographs of the samples with four check marks under PLM; a) Wall (plasterboard), b) Floor (textile-based floor covering), c) Insulation (insulating paper) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

Examination by PLM reveals that all varieties of six asbestos minerals with varying amounts are present in the 70 samples of the total 75 samples (Figures 3.23 – 3.28). Not only single variety but also mixture of more than varieties are detected in the samples. The types of asbestos minerals with their percentages in the samples of wall, floor and insulation are given in Figure 3.22. Chrysotile is the most common type of asbestos in the analyzed samples. The other asbestos types, which are Tremolite, Actinolite, Anthophyllite Amosite and Crocidolite, exist with variables amounts Figure 3.22.

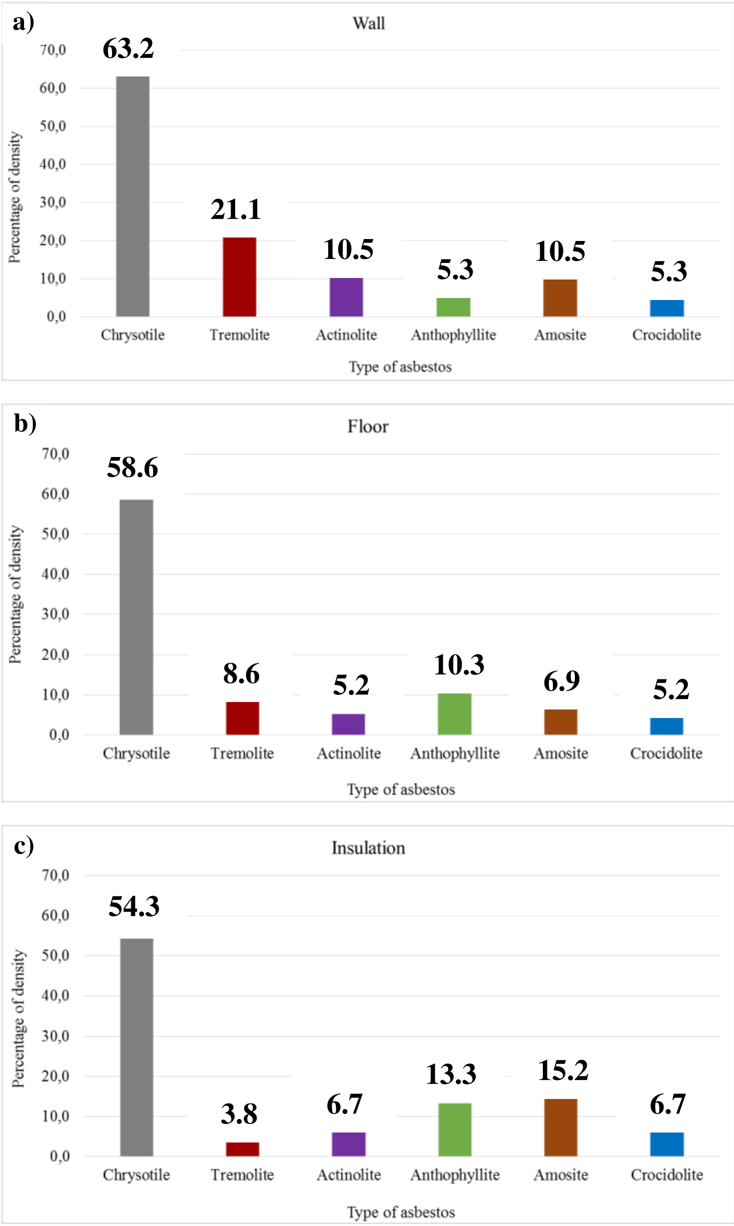


Figure 3.22. The graphs showing asbestos types vs. density percentages for a) wall, b) floor and c) insulation

i) Wall

13 samples from wall material happen to include varying types of asbestos (Table 3.14). Chrysotile is the most frequently seen type within whole wall samples with 63.2%.

Table 3.14. *Asbestos content of wall samples*

Sample no	Material type detail	Asbestos type
A-02	scratch coat	**Chrysotile, Amosite**
B-07	exposed concrete	**Tremolite**
C-04	finishing coat + wall paint	**Actinolite**
C-12	materials fragmented from main bodies	**Chrysotile**
D-19	materials fragmented from main bodies	**Chrysotile, Amosite**
D-38	scratch coat	**Chrysotile**
D-41	finishing coat	**Tremolite**
E-02	exposed concrete	**Chrysotile, Crocidolite**
E-18	plasterboard	**Tremolite**
E-35	scratch coat	**Chrysotile**
E-36	finishing coat	**Actinolite**
E-37	exposed concrete	**Chrysotile**
E-38	scratch coat	**Chrysotile**
E-42	finishing coat	**Anthophyllite**

ii) Floor

22 samples of floor material happen to include asbestos, as their types are given in Table 3.15. Chrysotile is the most frequently seen type within the entire wall samples with 58.6%.

Table 3.15. *Asbestos content of floor samples*

Sample no	Material type detail	Asbestos type
A-01	concrete	**Chrysotile**
A-06	concrete tile	**Chrysotile**
A-07	vinyl floor covering + concrete	**Chrysotile**

Table 3.15. *(continued)*

Sample no	Material type detail	Asbestos type
A-14	concrete	Chrysotile
A-15	vinyl floor covering	Chrysotile, Tremolite, Anthophyllite
A-18	VFC glue	Chrysotile, Actinolite
A-20	ceramic tile	Chrysotile, Anthophyllite
A-22	dust on the floor	Actinolite
B-02	vinyl floor covering + concrete	Chrysotile
B-03	concrete tile	Chrysotile, Actinolite
C-02	concrete tile	Tremolite
D-08	concrete tile	Crocidolite
D-10	concrete tile	Chrysotile
D-25	concrete	Chrysotile, Amosite, Tremolite
E-03	concrete tile	Chrysotile, Anthophyllite, Crocidolite
E-13	concrete	Chrysotile, Tremolite, Anthophyllite
E-14	concrete tile	Chrysotile, Tremolite, Amosite
E-20	concrete tile	Chrysotile, Anthophyllite
E-23	vinyl floor covering	Chrysotile, Anthophyllite, Crocidolite
E-24	concrete	Chrysotile
E-33	vinyl floor covering	Chrysotile
E-34	floor covering based textile	Chrysotile, Amosite

iii) Insulation

34 samples of insulation material happen to include asbestos, as their types are given in Table 3.16. Chrysotile is the most frequently seen type within whole wall samples with 54.3 percentage.

Table 3.16. *Asbestos content of insulation samples*

Sample no	Material type detail	Asbestos type
A-04	foamed sealant	Chrysotile
A-08	vibration absorber	Amosite
A-19	heat changer pipe insulation	Chrysotile, Tremolite, Anthophyllite, Amosite
A-21	heat changer pipe insulation	Chrysotile, Amosite
B-17	heat resistant rope	Chrysotile, Amosite
C-03	dropped ceiling	Chrysotile

Table 3.16. *(continued)*

Sample no	Material type detail	Asbestos type
C-06	insulation board filler glass wool	Chrysotile
C-13	insulating paper	Chrysotile, Tremolite, Crocidolite
C-16	pipe insulation	Chrysotile, Anthophyllite
C-17	heat resistant rope	Chrysotile, Anthophyllite
C-18	heat resistant rope	Amosite
C-19	pipe insulation	Chrysotile, Amosite
C-20	pipe insulation	Chrysotile, Amosite
C-21	pipe insulation	Chrysotile, Actinolite
C-22	melamine coated chipboard ceiling cladding	Chrysotile
D-27	pipe insulation	Chrysotile
D-28	heat changer pipe insulation	Chrysotile
D-29	heat changer pipe insulation	Actinolite
D-30	pipe insulation	Chrysotile, Actinolite
D-31	pipe insulation	Chrysotile
D-32	pipe insulation	Chrysotile
D-35	heat changer pipe insulation	Anthophyllite
D-36	heat changer pipe insulation	Chrysotile, Anthophyllite
D-37	heat changer pipe insulation	Chrysotile
E-19	pipe insulation	Chrysotile, Amosite, Crocidolite
E-26	heat changer pipe insulation	Chrysotile, Tremolite, Actinolite, Amosite
E-27	heat changer pipe insulation	Anthophyllite, Crocidolite
E-28	heat changer pipe insulation	Chrysotile, Tremolite
E-29	heat changer pipe insulation	Chrysotile, Amosite, Crocidolite
E-30	heat changer pipe insulation	Chrysotile, Anthophyllite
E-31	heat changer pipe insulation	Actinolite, Anthophyllite
E-39	heat changer pipe insulation	Amosite
E-40	heat changer pipe insulation	Anthophyllite, Amosite
E-44	melamine coated chipboard	Chrysotile, Anthophyllite, Amosite

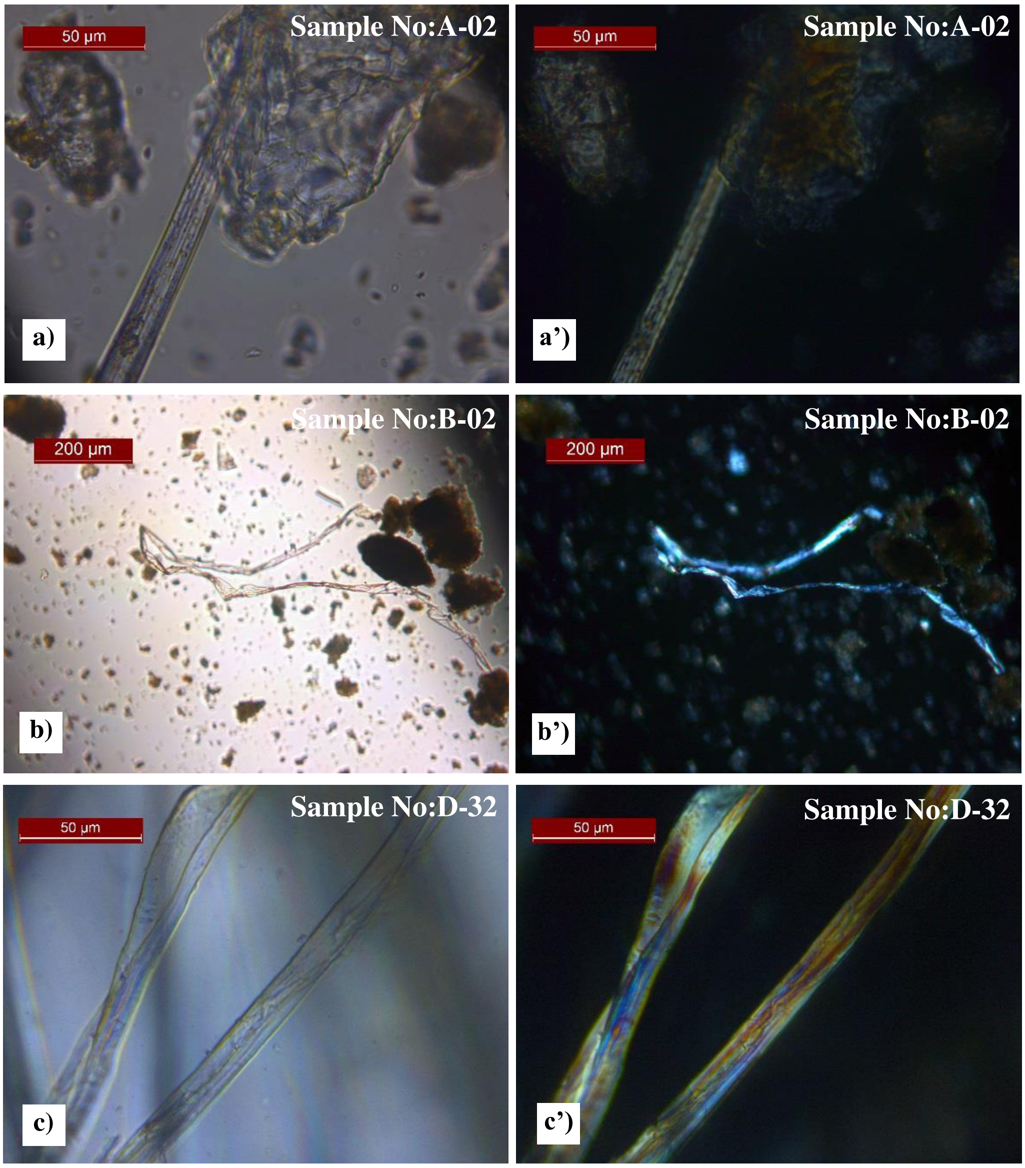


Figure 3.23. Representative micro-photographs for Chrysotile from; a) Wall (scratch coat), b) Floor (vinly floor covering + concrete) c) Insulation (pipe insulation) *[a, b, c are plane polarized lights, a', b', c' are cross polarized lights]*

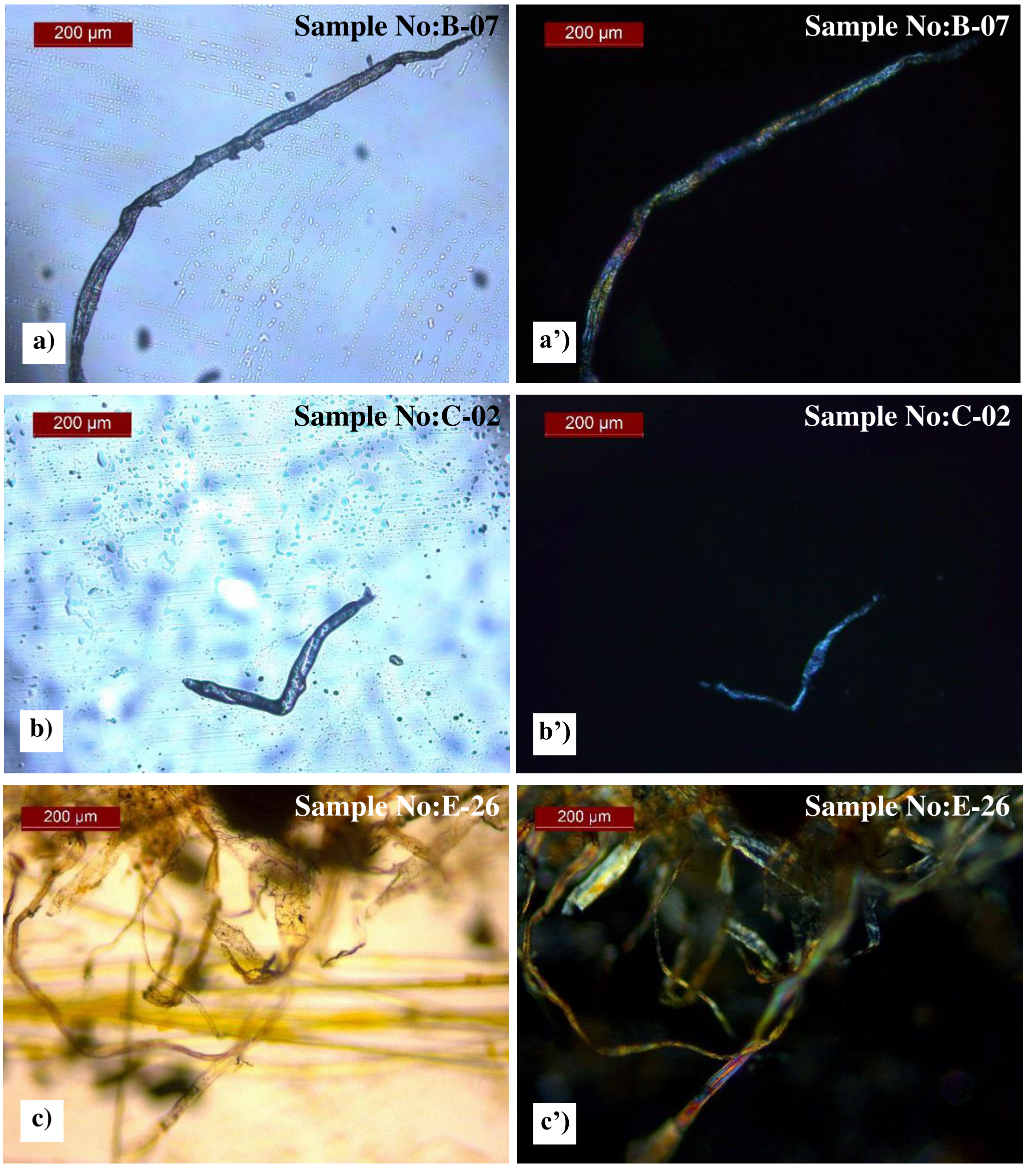


Figure 3.24. Representative micro-photographs for Tremolite in; a) Wall (exposed concrete), b) Floor (concrete tile), c) Insulation (pipe insulation) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

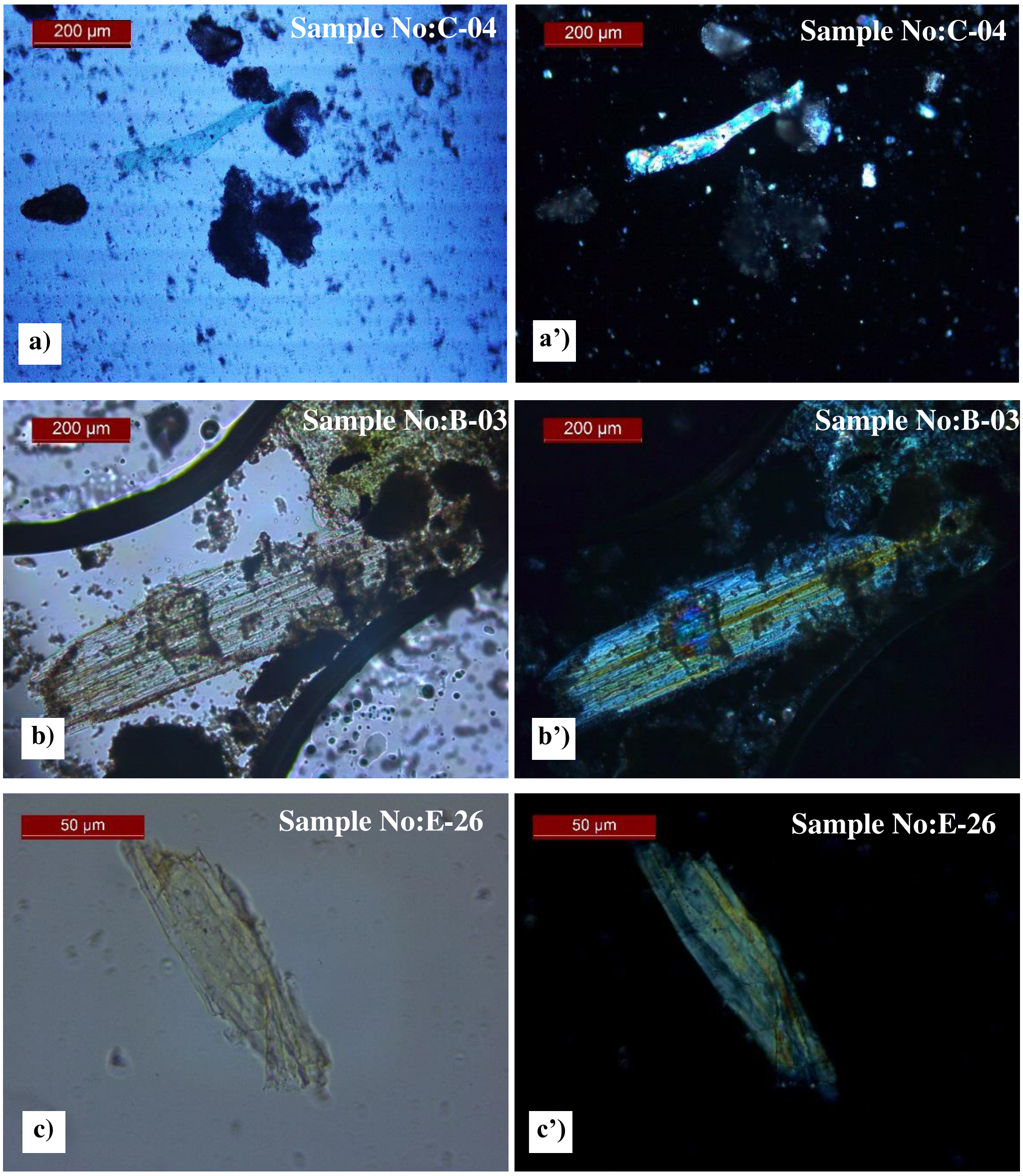


Figure 3.25. Representative micro-photographs for in Actinolite; a) Wall (finishing coat + wall paint), b) Floor (concrete tile) c) Insulation (pipe insulation) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

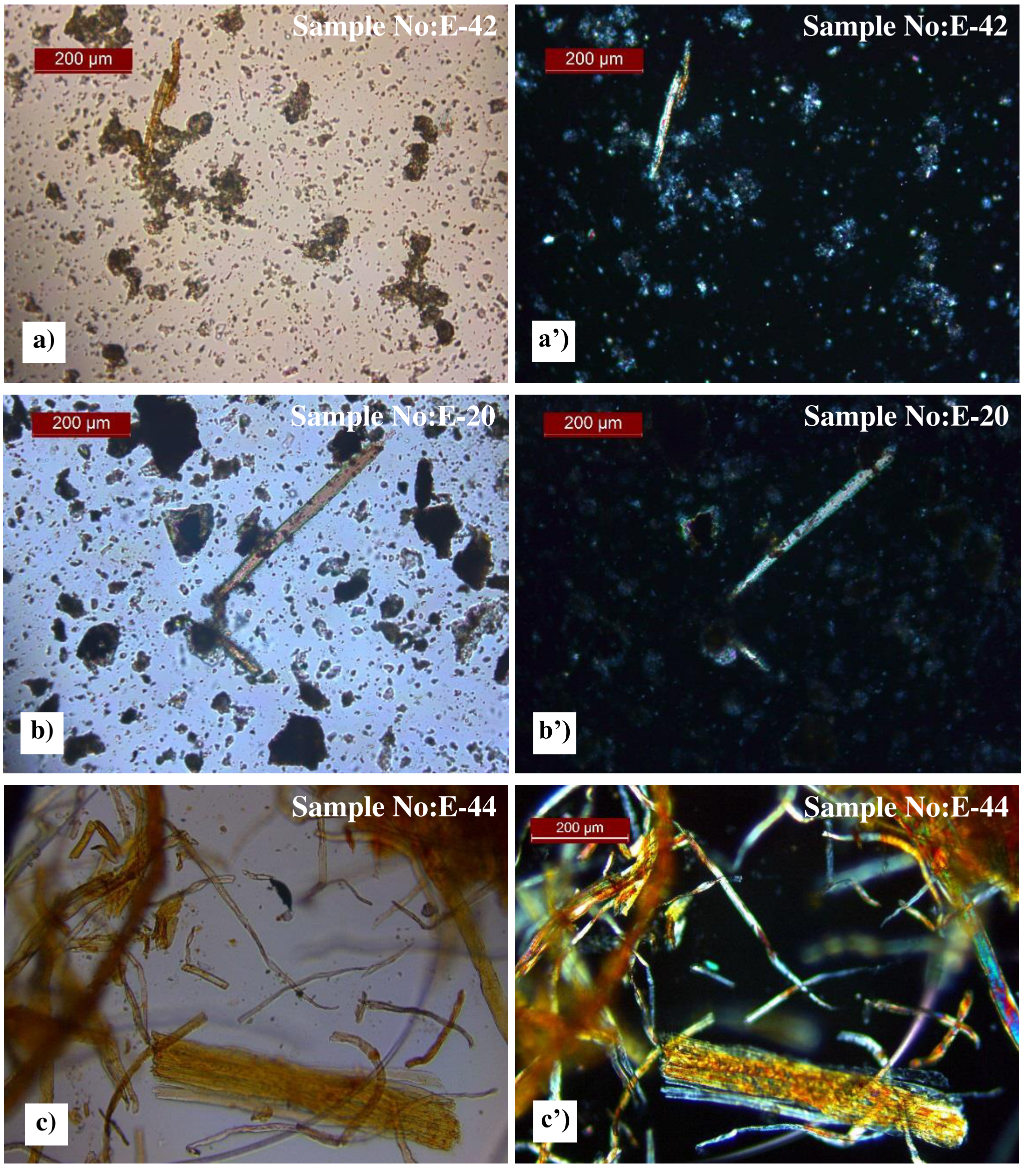


Figure 3.26. Representative micro-photographs for Anthophyllite in; a) Wall (finishing coat), b) Floor (concrete tile) c) Insulation (melamine coated chipboard) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

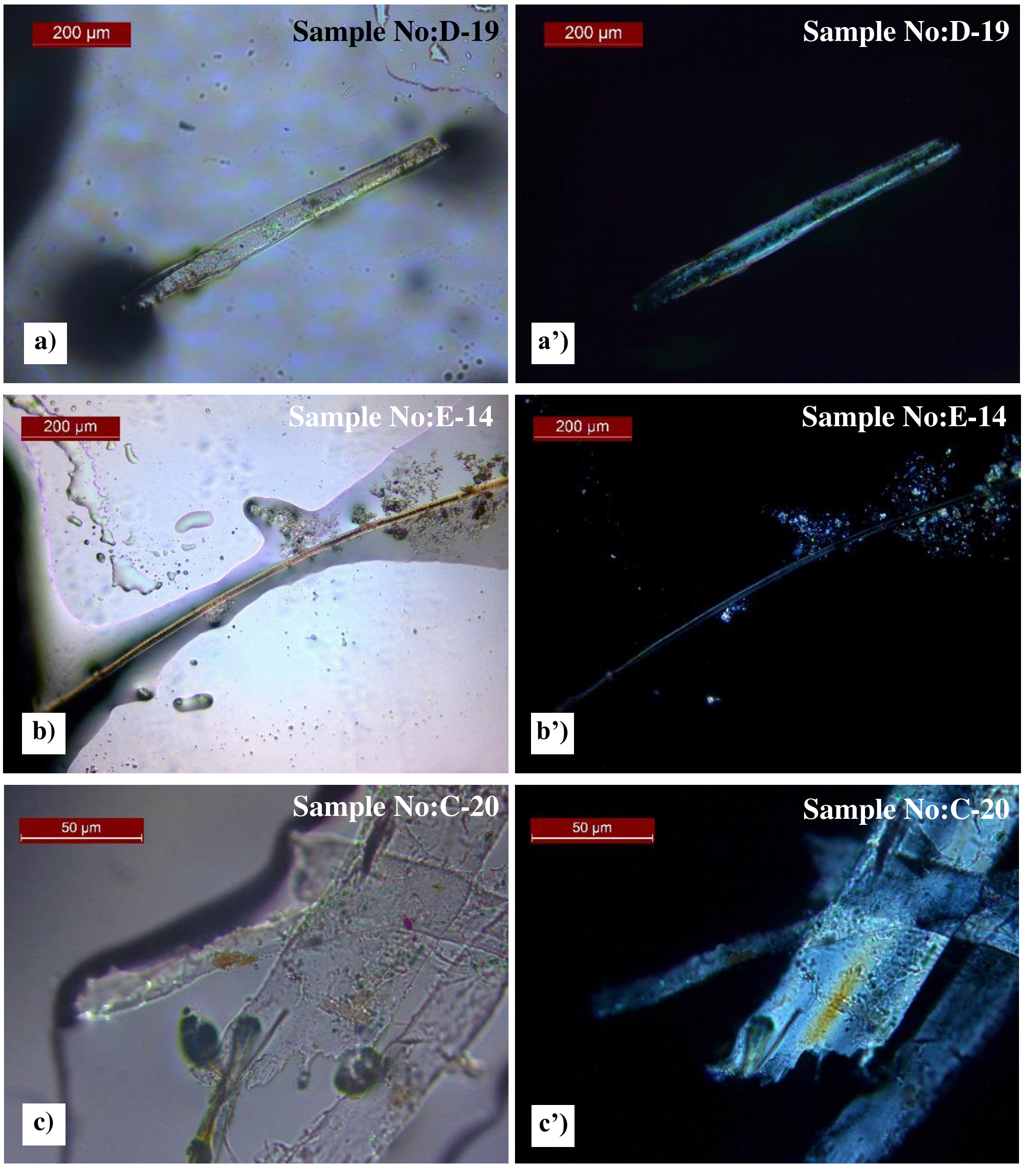


Figure 3.27. Representative micro-photographs for Amosite in; a) Wall (materials fragmented from main bodies), b) Floor (concrete tile) c) Insulation (pipe insulation) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

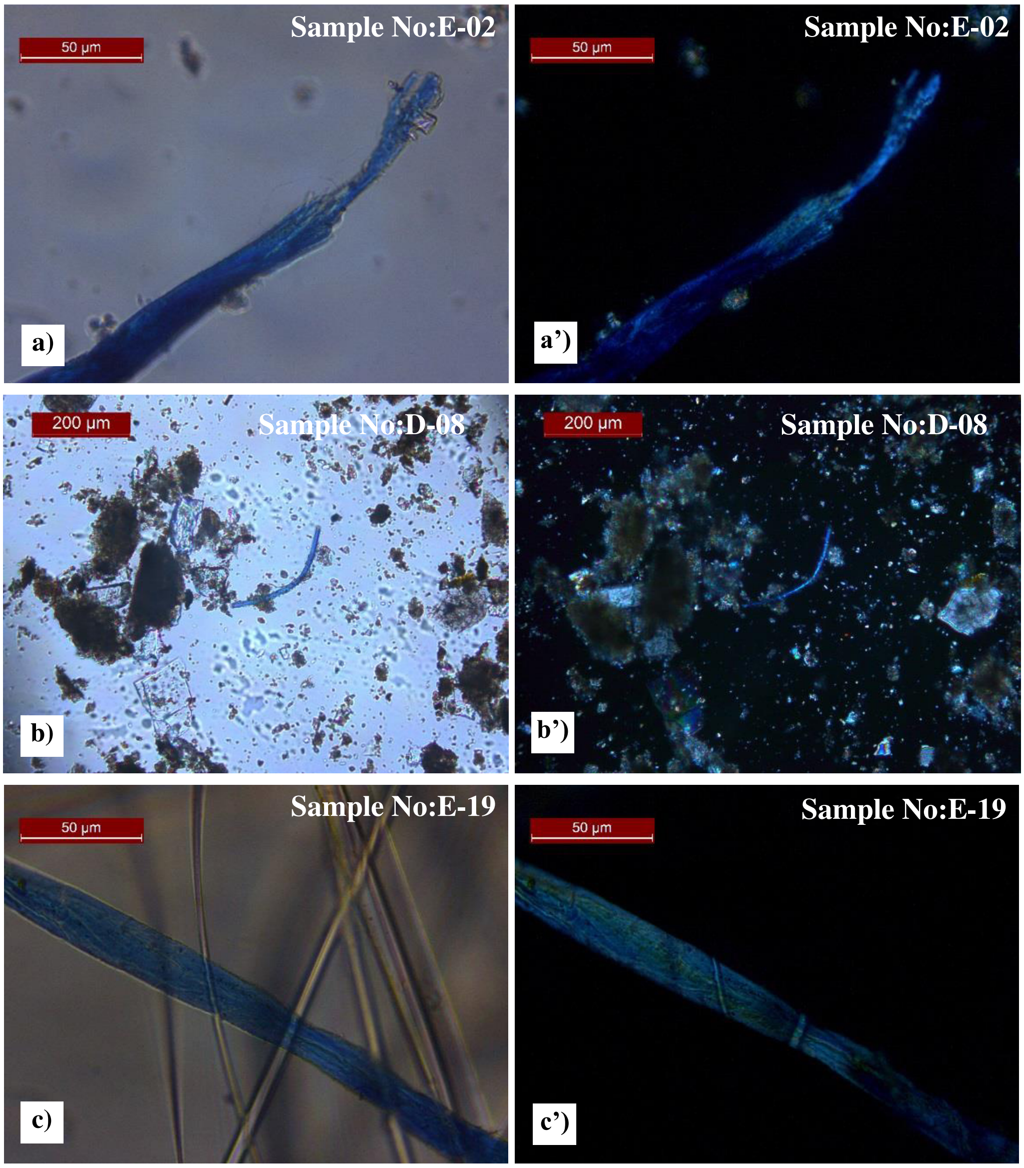


Figure 3.28. Representative micro-photographs for Crocidolite in; a) Wall (exposed concrete), b) Floor (concrete tile) c) Insulation (pipe insulation) *[a, b, c are plane polarized light, a', b', c' are cross polarized lights]*

CHAPTER 4

RISK ASSESSMENTS OF THE PILOT BUILDINGS

4.1. Building – A

The number of samples in Building-A is 22. The distributions of the samples according to the materials have been listed as 7 wall, 11 floor and 4 insulation materials. The wall samples include concrete, scratch coat and finishing coat, as well as different colored wall paint. On the other hand, floor materials include concrete, vinyl floor covering, ceramic tile and red and black colored concrete tile. Insulation materials involve both heat and vibration insulation through foamed sealant, vibration absorber and heat changer pipe insulation.

The percentage of each class which are analyzed in Section 1.4 from cross to four check marks are 9.1, 31.8, 31.8, 13.6 and 13.6, respectively. Moreover, the content of fibrous form in Building-A is shown in Table 4.1.

Table 4.1. *Fibrous content of Building-A's samples*

	Classification	**Explanation**
✕	2 wall	Finishing coat + wall paint
✓	4 wall, 3 floor	Concrete, finishing coat, Scratch/finishing coat + wall paint, concrete tile
✓✓	1 wall, 4 floor, 2 insulation	Scratch coat, concrete, concrete tile, ceramic tile, vinyl floor covering, foamed sealant, vibration absorber
✓✓✓	3 floor	Vinyl floor covering, VLC glue, powder material in the floor
✓✓✓✓	1 floor, 2 insulation	Concrete, heat changer pipe insulation

All asbestos types are present in construction materials of Building-A, and the details of the materials is shown in Table 4.2. Considering all materials in Building-A, Chrysotile is the most abundant variety, which is at 65.6% (Figure 4.1).

Table 4.2. *Asbestos contents of the samples from the Building-A*

	Sampled material	Material type	Asbestos type
✓✓	Wall (1)	Scratch coat	Chrysotile, Amosite
	Floor (4)	Concrete	Chrysotile
		Concrete tile	Chrysotile
		Ceramic tile	Chrysotile, Anthophyllite
		Vinyl floor covering	Chrysotile
	Insulation (2)	Foamed sealant	Chrysotile
		Vibration absorber	Amosite
✓✓✓	Floor (3)	Vinyl floor covering	Chrysotile, Anthophyllite, Tremolite
		VLC glue	Chrysotile, Actinolite
		Powder material in the floor	Actinolite
✓✓✓✓	Floor (1)	Concrete	Chrysotile
	Insulation (2)	Heat changer pipe insulation	Chrysotile, Amosite, Anthophyllite, Tremolite
		Heat changer pipe insulation	Chrysotile, Amosite

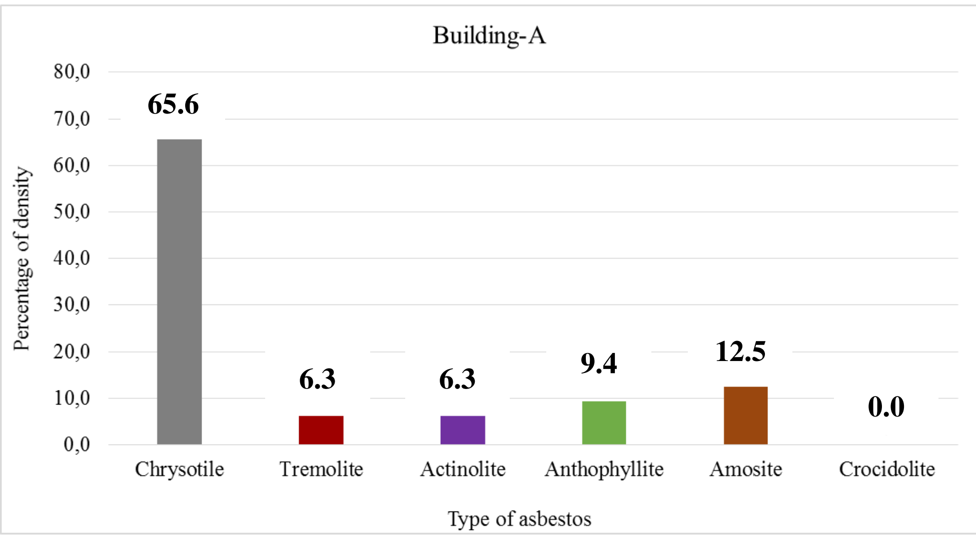


Figure 4.1. *Density of asbestos types in the samples from the Building-A*

It is of utmost importance for this building that the heat changer part is not located in a separate place. It is in an open area where the pipes are obviously seen and reached by the employees working in the building (Figure 4.2). This condition may be critical and hazardous for certain health issues.

Figure 4.2. The selected area for the risk assessment in Building-A *[red circle shows the sampling location]*

Therefore, the risk assessment is applied for the area of heat exchanger (Table 4.3 and Table 4.4). The selected sample used in assessment is A-21, which is a heat changer pipe insulation material.

Table 4.3. *Material assessment algorithm of the sample A-21*

Product type (or debris from product)	3	Thermal insulation (e.g. pipe and boiler lagging), sprayed asbestos, loose asbestos, asbestos mattresses and packing	**Total score is 10**
Extent of damage / deterioration	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres	
Surface treatment	3	Unsealed laggings and sprays	
Asbestos type	2	Amphibole asbestos excluding crocidolite	

Table 4.4. *Priority assessment algorithm of the sample A-21*

Normal occupant activity		**Score: 3**	**Total score is 10**
Main type of activity in area	3	High levels of disturbance, (e.g. fire door with asbestos insulating board sheet in constant use)	
Likelihood of disturbance		**Score: 2**	
Location	2	Rooms up to 100 m^2	
Accessibility	3	Routinely disturbed	
Extent/amount	1	≤ 10 m^2 or ≤ 10 m pipe run.	
Human exposure potential		**Score: 3**	
Number of occupants	3	>10	
Frequency of use of area	3	Daily	
Average time area is in use	3	>6 hours	
Maintenance activity		**Score: 2**	
Type of maintenance activity	2	Medium disturbance (e.g. lifting one or two asbestos insulating board ceiling tiles to access a valve)	
Frequency of maintenance activity	2	>1 per year	

The equation of asbestos risk assessment is given below:

Material assessment score for each ACM		Priority assessment score for each ACM		Risk assessment score for each ACM
10	+	**10**	=	**20**

The obtained values of 20 during asbestos risk assessment, makes clear that the area is in Category A with a high level of risk. The selected sample used in assessment is A-21, which is shown Figure 4.3. Even though this sample is from a glass wool, asbestos is also present in it.

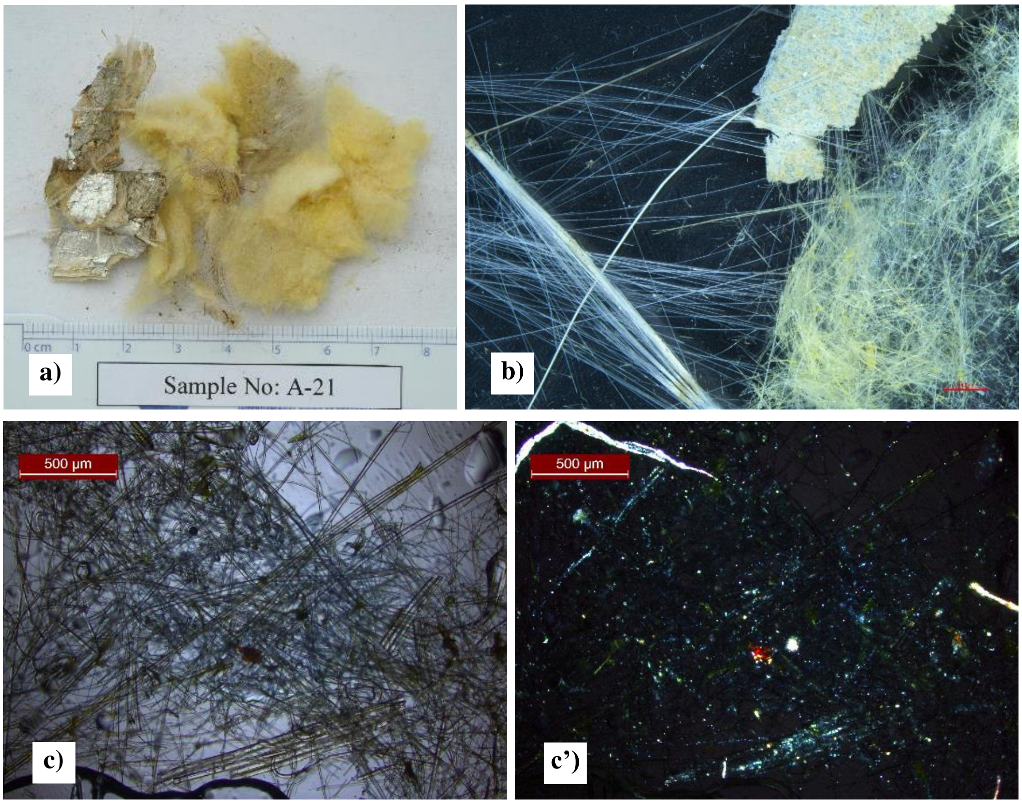


Figure 4.3. Macro to micro photographs of the sample A-21; a) sample's general view b) SM view, c&c') PLM view

4.2. Building – B

The number of samples in Building-B is 17. The distributions of samples based on the materials are listed as 9 wall, 6 floor and 2 insulation. The wall samples include exposed concrete, brick, two types of coat (scratch and finishing), and wall paint with different colors. On the other hand, floor materials include concrete, vinyl floor covering, green and white colored concrete tile. The heat exchanger part of this building is not easily accessible in the building. For this reason, the collected sample of insulation materials is only from foamed sealant and heat resistant rope. The distribution samples in the percentage of classes from cross to four check marks are given in Section 1.4 are 47.1, 29.4, 17.6, 0.0 and 5.9 in respectively. Moreover, the content of fibrous form in the samples from Building-B is shown in Table 4.5. Four asbestos types are present in the materials of Building-B (Table 4.6). Considering all materials in Building-B, Chrysotile is the most dominant one with 62.5% (Figure 4.4).

Table 4.5. *Fibrous density of the samples from the Building-B*

	Classification	Explanation
✕	6 wall, 2 floor	Scratch coat + wall paint, finishing coat, concrete, concrete tile
✓	2 wall, 2 floor, 1 insulation	Brick, exposed concrete, concrete, concrete tile, foamed sealant
✓✓	1 wall, 2 floor	Exposed concrete, vinyl floor covering + concrete, concrete tile
✓✓✓	-	-
✓✓✓✓	1 insulation	Heat resistant rope

Table 4.6. *Asbestos content of the samples from the Building-B*

	Sampled material	Material type	Asbestos type
✓✓	Wall (1)	Exposed concrete	Tremolite
	Floor (2)	Vinyl floor covering + concrete	Chrysotile
		Concrete tile	Chrysotile, Actinolite
✓✓✓✓	Insulation (1)	Heat resistant rope	Chrysotile, Amosite

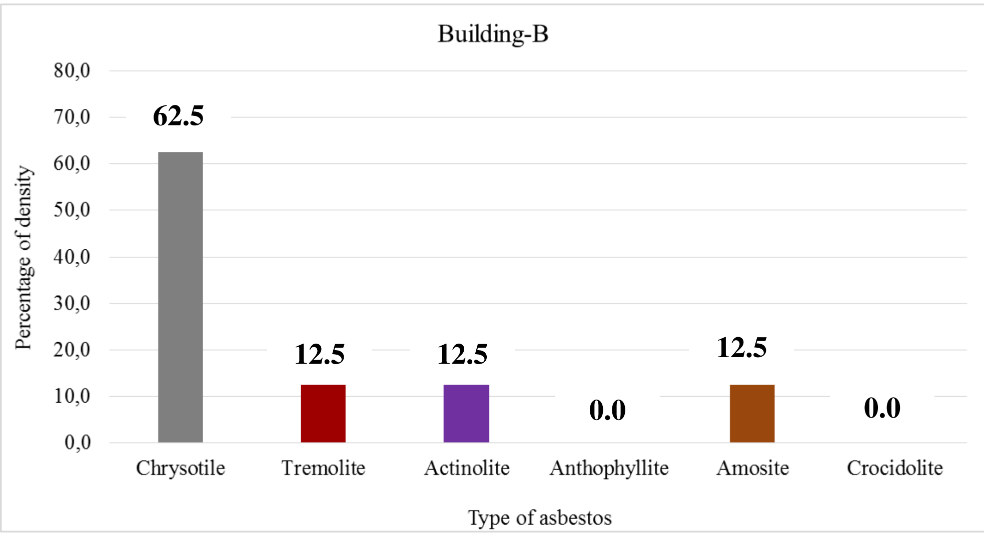


Figure 4.4. Density of asbestos types in the samples from the Building-B

The one and only four check marked sample is heat resistant rope among all the samples. This sample is assumed to be representative of the other buildings' central heating component, as well. Old ropes do not have a huge dimension, but they are used currently for the connecting piece. For that reason, the assessment of the sample B-17 is applied (Table 4.7 and Table 4.8), and the risk assessment is used for this sample and its surroundings (Figure 4.5).

Figure 4.5. The selected area for risk assessment in the Building-B *[red circle shows the sampling location]*

Table 4.7. *Material assessment algorithm of the sample B-17*

Product type (or debris from product)	2	Asbestos insulating board, mill boards, other low density insulation boards, asbestos textiles, gaskets, ropes and woven textiles, asbestos paper and felt	**Total score is 8**
Extent of damage / deterioration	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres	
Surface treatment	2	Unsealed asbestos insulating board, or encapsulated lagging and sprays	
Asbestos type	2	Amphibole asbestos excluding crocidolite	

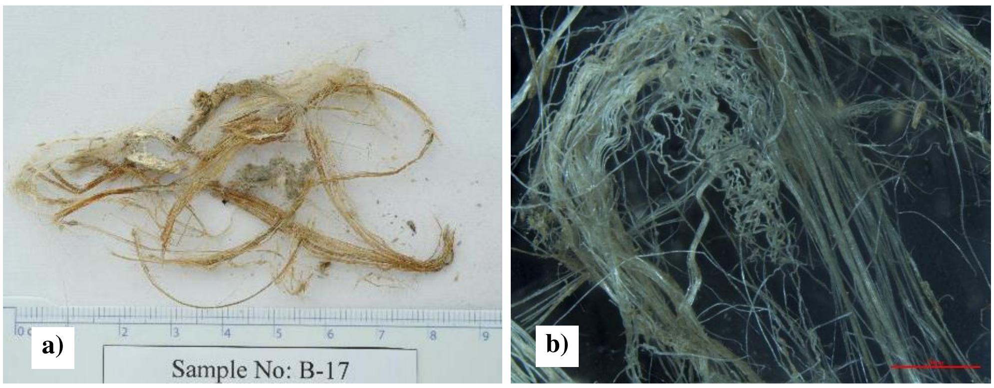
Table 4.8. *Priority assessment algorithm of sample B-17*

<table>
<tr><td colspan="2">Normal occupant activity</td><td>Score: 1</td><td rowspan="16">Total score is 5.7</td></tr>
<tr><td>Main type of activity in area</td><td>1</td><td>Periodic disturbance (e.g. industrial or vehicular activity which may contact ACMs)</td></tr>
<tr><td colspan="2">Likelihood of disturbance</td><td>Score: 1</td></tr>
<tr><td>Location</td><td>1</td><td>Large rooms or well-ventilated areas</td></tr>
<tr><td>Accessibility</td><td>2</td><td>Easily disturbed</td></tr>
<tr><td>Extent/amount</td><td>0</td><td>Small amounts or items (e.g. strings, gaskets)</td></tr>
<tr><td colspan="2">Human exposure potential</td><td>Score: 2.7</td></tr>
<tr><td>Number of occupants</td><td>2</td><td>4 to 10</td></tr>
<tr><td>Frequency of use of area</td><td>3</td><td>Daily</td></tr>
<tr><td>Average time area is in use</td><td>3</td><td>>6 hours</td></tr>
<tr><td colspan="2">Maintenance activity</td><td>Score: 1</td></tr>
<tr><td>Type of maintenance activity</td><td>1</td><td>Low disturbance (e.g. changing light bulbs in asbestos insulating board ceiling)</td></tr>
<tr><td>Frequency of maintenance activity</td><td>1</td><td>≤1 per year</td></tr>
</table>

The equation of asbestos risk assessment is given below:

Material assessment score for each ACM		Priority assessment score for each ACM		Risk assessment score for each ACM
8	+	**5.7**	=	**13.7**

The calculated asbestos risk assessment, which is about 14, points out that the area is in Category B with a medium risk level. The selected sample (B-17) used during the assessment is shown in Figure 4.6.



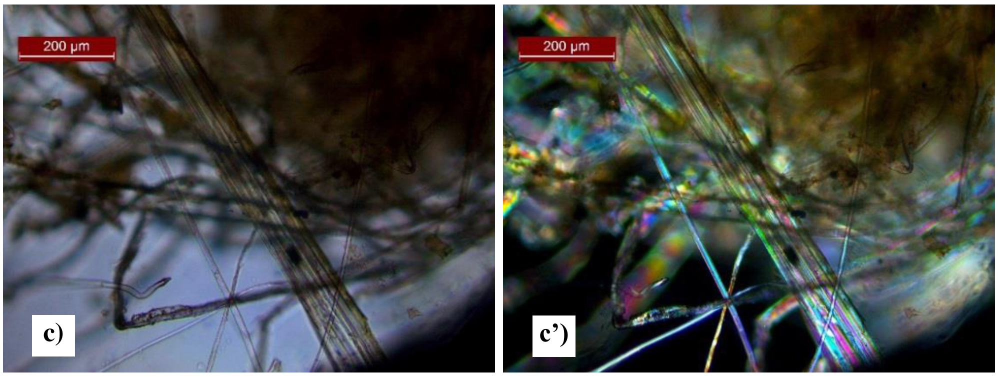


Figure 4.6. Macro to micro photographs of the sample B-17; a) sample's general view b) SM view, c&c') PLM view

4.3. Building – C

The number of samples in the Building-C is 23. The distribution of the samples based on the materials are listed as 11 wall, 2 floor and 10 insulation. The wall samples include exposed concrete, brick, concrete, plasterboard, scratch coat, finishing coat, and different colored wall paints. On the other hand, floor materials include ceramic tile, red and white colored concrete tile. Insulation materials involve dropped ceiling, melamine coated chipboard ceiling cladding, insulating paper, heat resistant rope, insulation board and pipe insulation. The percentage of classes from cross to four check marks given in Section 1.4 are 4.3, 30.4, 17.4, 8.7 and 39.1, correspondingly. In addition, the content of fibrous form in the samples from the Building-C is given in Table 4.9. All asbestos types are present in the samples from the Building-C (Table 4.10). Considering all materials in the Building-C, Chrysotile has the highest rate at 60.6% (Figure 4.7).

Table 4.9. *Fibrous content of the samples from the Building-C*

	Classification	**Explanation**
✕	1 wall	Finishing coat + wall paint
✓	6 wall, 1 floor	Brick, exposed concrete, concrete, scratch coat + wall paint, scratch coat, plasterboard, finishing coat, ceramic tile
✓✓	3 wall, 1 floor	Finishing coat + wall paint, brick, concrete tile
✓✓✓	1 wall, 1 insulation	Materials fragmented from main bodies, melamine coated chipboard ceiling cladding
✓✓✓✓	9 insulation	Heat resistant rope, dropped ceiling, insulation paper, pipe insulation, insulation board filler glass wool

Table 4.10. *Asbestos content of the samples from the Building-C*

	Sampled material	**Material type**	**Asbestos type**
✓✓	Wall (1)	Finishing coat + wall paint	**Actinolite**
	Floor (1)	Concrete tile	**Tremolite**
✓✓✓	Wall (1)	Materials fragmented from main bodies	**Chrysotile**
	Insulation (1)	Melamine coated chipboard ceiling cladding	**Chrysotile**
✓✓✓✓	Insulation (9)	Dropped ceiling	**Chrysotile**
		Insulation board filler glass wool	**Chrysotile**
		Heat resistant rope	**Chrysotile, Anthophyllite**
		Heat resistant rope	**Amosite**
		Insulation paper	**Chrysotile, Tremolite, Crocidolite**
		Pipe insulation	**Chrysotile, Anthophyllite**
		Pipe insulation	**Chrysotile, Amosite**
		Pipe insulation	**Chrysotile, Amosite**
		Pipe insulation	**Chrysotile, Actinolite**

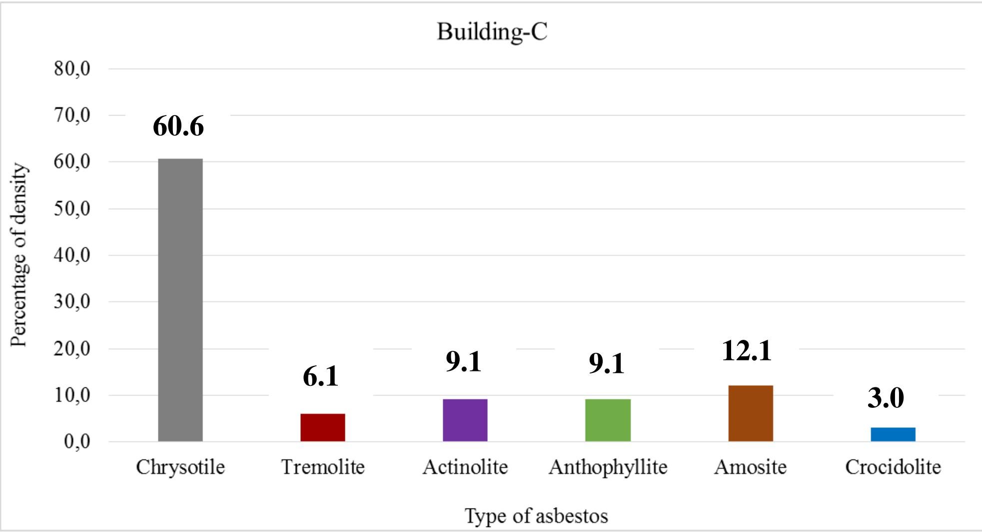


Figure 4.7. Density of asbestos types in the samples from the Building-C

The risk assessment is applied for a storage room that was used as an office until a few years ago (Figure 4.8). Inside, there are various materials which are highly deformed. For example, the pipes are obviously seen due to deformed dropped ceiling, and insulation paper is reachable easily because of the distorted plasterboard.

Figure 4.8. The selected area for risk assessment in the Building-C *[red circle shows the sampling location]*

This room is located on a floor in which different offices are used regularly. Moreover, there is no insulated entrance for this depot area. Consequently, the selected room happens to be the most critical area in Building-C. Also, the sample C-13 which is insulating paper is considered when assessing the risk score (Table 4.11 and Table 4.12).

Table 4.11. *Material assessment algorithm of the sample C-13*

Product type (or debris from product)	2	Asbestos insulating board, mill boards, other low-density insulation boards, asbestos textiles, gaskets, ropes and woven textiles, asbestos paper and felt	**Total score is 8**
Extent of damage / deterioration	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres	
Surface treatment	1	Enclosed sprays and lagging, asbestos insulating board (with exposed face painted or encapsulated), asbestos cement sheets etc.	
Asbestos type	3	Crocidolite	

Table 4.12. *Priority assessment algorithm of sample C-13*

Normal occupant activity		**Score: 1**	**Total score is 5.3**
Main type of activity in area	1	Periodic disturbance (e.g. industrial or vehicular activity which may contact ACMs)	
Likelihood of disturbance		**Score: 2**	
Location	2	Rooms up to 100 m^2	
Accessibility	2	Easily disturbed	
Extent/amount	2	>10 m^2 to ≤50 m^2 or >10 m to ≤50 m pipe run	
Human exposure potential		**Score: 0.3**	
Number of occupants	1	1 to 3	
Frequency of use of area	0	Infrequent	
Average time area is in use	0	<1 hour	
Maintenance activity		**Score: 2**	
Type of maintenance activity	3	High levels of disturbance (e.g. removing a number of asbestos insulating board ceiling tiles to replace a valve or for recabling)	
Frequency of maintenance activity	1	≤1 per year	

The equation of asbestos risk assessment is given below:

Material assessment score for each ACM	+	Priority assessment score for each ACM	=	Risk assessment score for each ACM
8		**5.3**		**13.3**

The calculated asbestos risk assessment, about 14, explains that the area is in Category B with medium risk level. The selected sample (C-13) used in the assessment is shown in Figure 4.9.

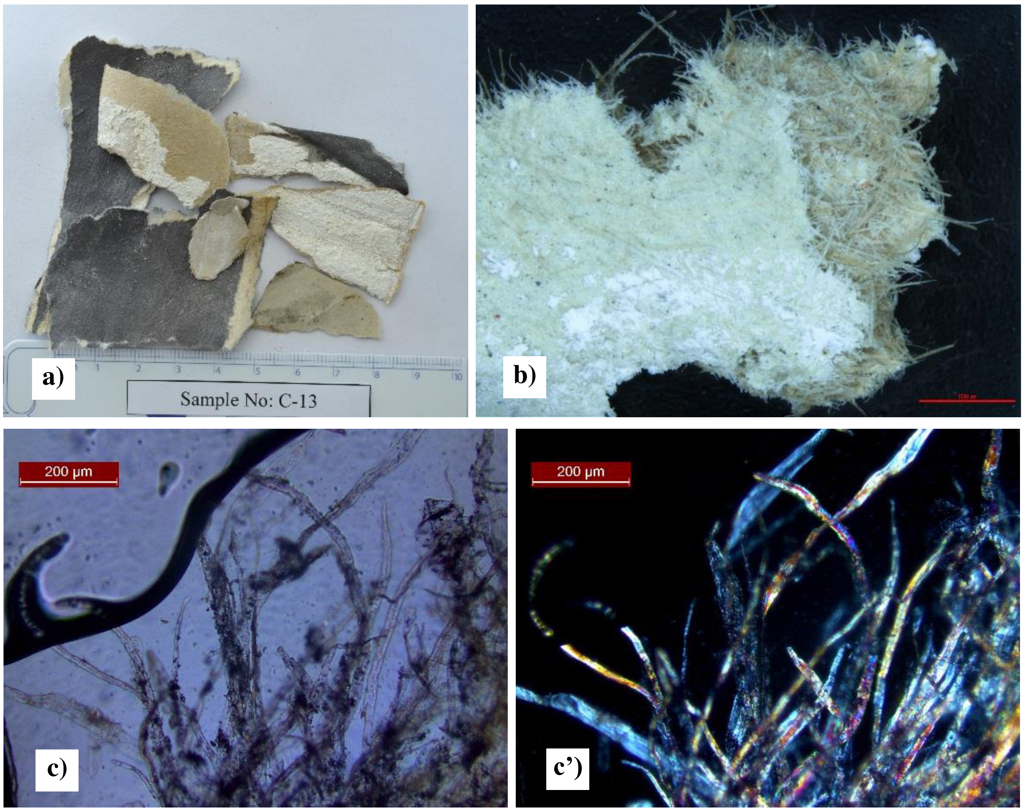


Figure 4.9. Macro to micro photographs of the sample C-13; a) sample's general view b) SM view, c&c') PLM view

4.4. Building – D

The number of samples in Building-D is 43. The distributions of the samples based on the materials are listed as 28 wall, 6 floor and 9 insulation. The wall samples include marble, concrete, brick, scratch coat, finishing coat, and different colored wall paint. On the other hand, floor materials include concrete, ceramic tile, mosaic and white colored concrete tile. Insulation materials involve pipe insulation and heat changer pipe insulation. The percentage of classes from cross to four check marks given Section 1.4, which are 23.3, 41.9, 11.6, 2.3 and 20.9, accordingly. Moreover, the content of fibrous form in the Building-D is given in Table 4.13.

Table 4.13. *Fibrous content of the samples from the Building-D*

	Classification	**Explanation**
✕	7 wall, 3 floor	Scratch coat + wall paint, marble, scratch coat, scratch/finishing coat, finishing coat + wall paint, finishing coat, concrete tile, ceramic tile
✓	18 wall	Brick, concrete, scratch coat + wall paint, scratch coat, finishing coat, concrete
✓✓	3 wall, 2 floor	Materials fragmented from main bodies, finishing coat, scratch coat, concrete tile
✓✓✓	1 floor	Concrete
✓✓✓✓	9 insulation	Heat changer pipe insulation, pipe insulation

All asbestos types are present in the samples from the Building-D (Table 4.13). Considering all materials in Building-D, Chrysotile has the highest rate at 71.8% (Figure 4.7).

Table 4.14. *Asbestos content of the samples from the Building-D*

	Sampled material	**Material type**	**Asbestos type**
✓✓	Wall (3)	Finishing coat	**Tremolite**
		Scratch coat	**Chrysotile**
		Materials fragmented from main bodies	**Chrysotile, Amosite**

Table 4.14. *(continued)*

	Sampled material	Material type	Asbestos type
✓✓	Floor (2)	Concrete tile	Chrysotile
		Concrete tile	Crocidolite
✓✓✓	Floor (1)	Concrete	Chrysotile, Amosite, Tremolite
✓✓✓✓	Insulation (9)	Heat changer pipe insulation	Chrysotile
		Heat changer pipe insulation	Actinolite
		Heat changer pipe insulation	Anthophyllite
		Heat changer pipe insulation	Chrysotile, Anthophyllite,
		Heat changer pipe insulation	Chrysotile
		Pipe insulation	Chrysotile
		Pipe insulation	Chrysotile, Actinolite
		Pipe insulation	Chrysotile
		Pipe insulation	Chrysotile

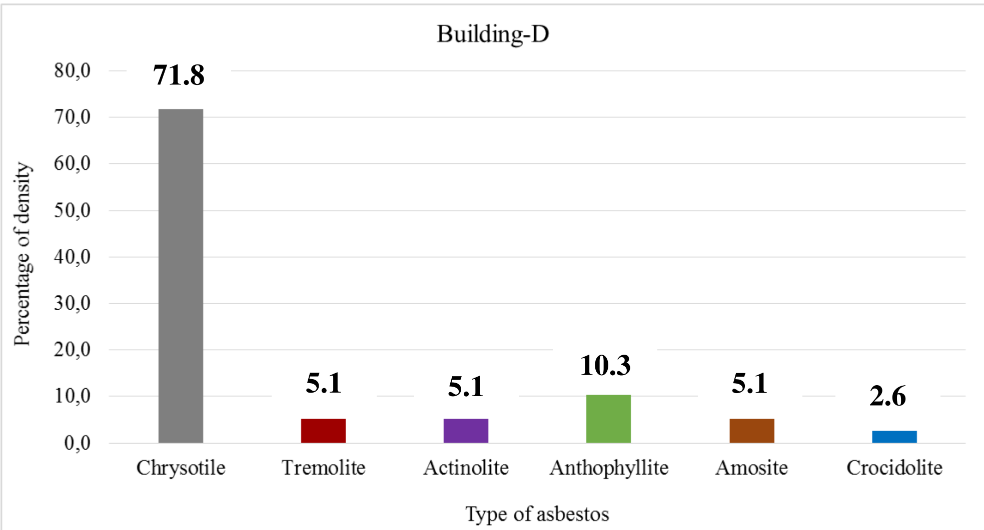


Figure 4.10. Density of asbestos types in the samples from the Building-D

The risk assessment is applied for a storage floor on which whole water pipes and vent pipes are present, not closed with any structure. Insulation materials are seen obviously due to deformation of covering (Figure 4.11).

Figure 4.11. Selected area for risk assessment in Building-D *[red circle shows the sampling location]*

There are numerous deformed pipe insulations in the area, from where the sample D-30 is selected as a representative of the assessment of the risk score (Table 4.15 and Table 4.16).

Table 4.15. *Material assessment algorithm of the sample D-30*

Product type (or debris from product)	3	Thermal insulation (e.g. pipe and boiler lagging), sprayed asbestos, loose asbestos, asbestos mattresses and packing	**Total score is 10**
Extent of damage / deterioration	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres	
Surface treatment	3	Unsealed laggings and sprays	
Asbestos type	2	Amphibole asbestos excluding crocidolite	

Table 4.16. *Priority assessment algorithm of the sample D-30*

<table>
<tr><td colspan="2">Normal occupant activity</td><td>Score: 0</td><td rowspan="14">Total score is 4.3</td></tr>
<tr><td>Main type of activity in area</td><td>0</td><td>Rare disturbance activity (e.g. little used store room)</td></tr>
<tr><td colspan="2">Likelihood of disturbance</td><td>Score: 2</td></tr>
<tr><td>Location</td><td>1</td><td>Large rooms or well-ventilated areas</td></tr>
<tr><td>Accessibility</td><td>2</td><td>Easily disturbed</td></tr>
<tr><td>Extent/amount</td><td>3</td><td>>50 m^2 or >50 m pipe run</td></tr>
<tr><td colspan="2">Human exposure potential</td><td>Score: 1.3</td></tr>
<tr><td>Number of occupants</td><td>1</td><td>1 to 3</td></tr>
<tr><td>Frequency of use of area</td><td>2</td><td>Weekly</td></tr>
<tr><td>Average time area is in use</td><td>1</td><td>>1 to <3 hours</td></tr>
<tr><td colspan="2">Maintenance activity</td><td>Score: 1</td></tr>
<tr><td>Type of maintenance activity</td><td>1</td><td>Low disturbance (e.g. changing light bulbs in asbestos insulating board ceiling)</td></tr>
<tr><td>Frequency of maintenance activity</td><td>1</td><td>≤1 per year</td></tr>
</table>

The equation of asbestos risk assessment is given below:

Material assessment score for each ACM **10**	+	Priority assessment score for each ACM **4.3**	=	Risk assessment score for each ACM **14.3**

The calculated asbestos risk assessment, about 14, indicates that the area is in Category B with a medium risk level. The selected sample (D-30) used in assessment is shown in Figure 4.12.

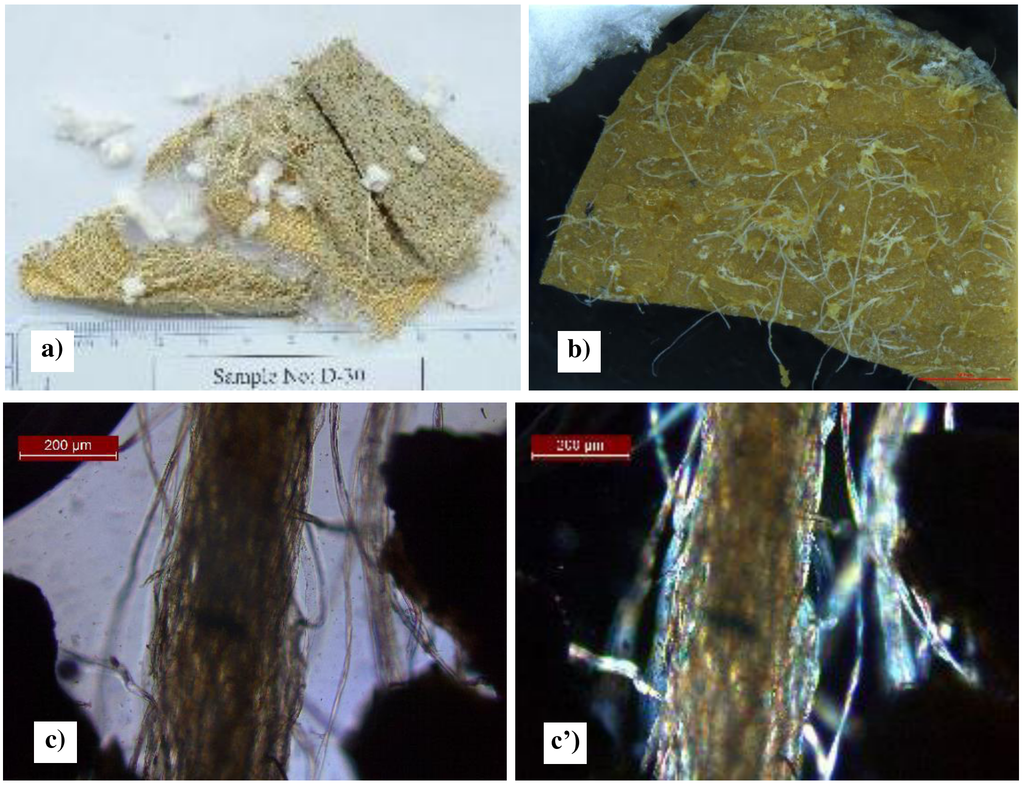


Figure 4.12. Macro to micro photographs of the sample D-30; a) sample's general view b) SM view, c&c') PLM view

4.5. Building – E

The number of samples in Building-E is 45. The distributions of samples based on the materials are listed as 22 wall, 13 floor and 10 insulation. The wall samples include exposed concrete, marble, plasterboard, concrete, scratch coat, finishing coat and different colored wall paint. Contrarily, floor materials include epoxy, concrete, vinyl floor covering, beige, white and green colored concrete tile. Insulation materials are pipe insulation, melamine coated chipboard and heat changer pipe insulation.

The percentage of classes denoted with a cross to four check marks are given Section 1.4 are 13.3, 24.5, 22.2, 6.7 and 33.3, respectively. Also, the content of fibrous form regarding Building-E is cited in Table 4.17.

Table 4.17. *Fibrous content of the samples from the Building-E*

	Classification	Explanation
✕	6 wall	Finishing coat, concrete
✓	8 wall, 3 floor	Concrete, scratch coat + wall paint, scratch coat, exposed concrete, scratch/finishing coat, finishing coat, concrete tile
✓✓	6 wall, 4 floor	Marble, scratch coat, finishing coat, exposed concrete, vinyl floor covering, concrete tile, concrete
✓✓✓	3 floor	Concrete, concrete tile, epoxy
✓✓✓✓	2 wall, 3 floor, 10 insulation	Exposed concrete, plasterboard, concrete, vinyl floor covering, floor covering based textile, pipe insulation, melamine coated chipboard, heat changer pipe insulation

All asbestos types are present in the samples from Building-E (Table 4.18). Comparing all materials in Building-E, Chrysotile has the highest rate at 41.4% (Figure 4.13).

Table 4.18. *Asbestos content of the samples from the Building-E*

	Sampled material	Material type	Asbestos type
✓✓	Wall (5)	Scratch coat	**Chrysotile**
		Scratch coat	**Chrysotile**
		Finishing coat	**Actinolite**
		Finishing coat	**Anthophyllite**
		Exposed concrete	**Chrysotile**
	Floor (3)	Concrete tile	**Chrysotile, Anthophyllite**
		Concrete	**Chrysotile**
		Vinyl floor covering	**Chrysotile, Anthophyllite, Crocidolite**
✓✓✓	Floor (1)	Concrete	**Chrysotile**
✓✓✓✓	Wall (2)	Exposed concrete	**Chrysotile, Crocidolite**
		Plasterboard	**Tremolite**
	Floor (3)	Concrete	**Chrysotile, Tremolite, Anthophyllite**
		Vinyl floor covering	**Chrysotile**
		Floor covering based textile	**Chrysotile, Amosite**

Table 4.18. *(continued)*

	Sampled material	Material type	Asbestos type
✓✓✓✓	Insulation (10)	Pipe insulation	Chrysotile, Amosite, Crocidolite
		Melamine coated chipboard	Chrysotile, Anthophyllite, Amosite
		Heat changer pipe insulation	Chrysotile, Tremolite, Actinolite, Amosite
		Heat changer pipe insulation	Anthophyllite, Crocidolite
		Heat changer pipe insulation	Chrysotile, Tremolite
		Heat changer pipe insulation	Chrysotile, Amosite, Crocidolite
		Heat changer pipe insulation	Chrysotile, Anthophyllite
		Heat changer pipe insulation	Actinolite, Anthophyllite
		Heat changer pipe insulation	Amosite
		Heat changer pipe insulation	Anthophyllite, Amosite

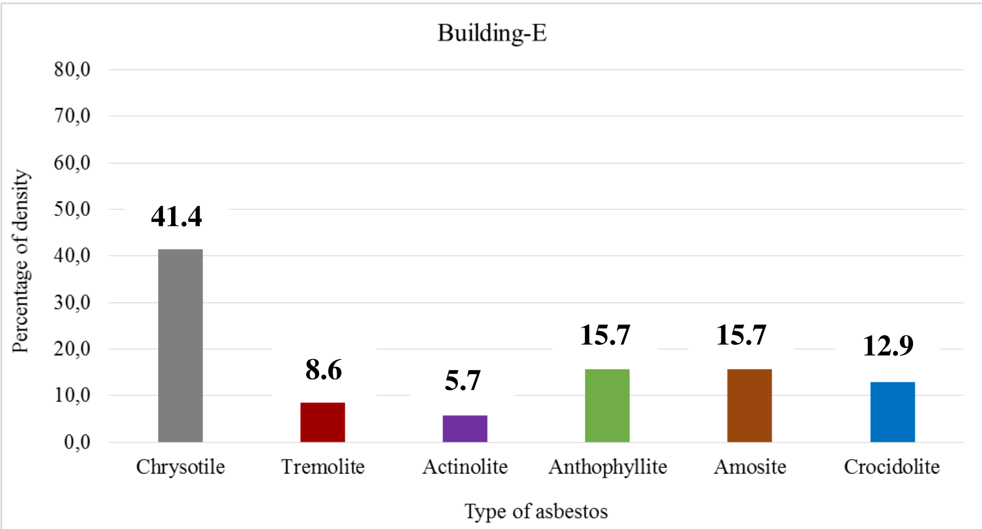


Figure 4.13. Density of asbestos types in the samples from the Building-E

The risk assessment is applied for the area between the heat changer room and the office corridor. In this area, solely a melamine coated chipboard is used as a separator (Figure 4.14). Furthermore, there is no insulated entrance for this heat changer area.

Figure 4.14. The selected area for risk assessment in the Building-E *[red circle shows the sampling location]*

This region is selected as the most critical area in Building-E, which is also where the sample E-44 (melamine coated chipboard) is chosen as a representative of the assessment of the risk score (Table 4.19 and Table 4.20).

Table 4.19. *Material assessment algorithm of the sample E-44*

Product type (or debris from product)	2	Asbestos insulating board, mill boards, other low density insulation boards, asbestos textiles, gaskets, ropes and woven textiles, asbestos paper and felt	**Total score is 8**
Extent of damage / deterioration	2	Medium damage: significant breakage of materials or several small areas where material has been damaged revealing loose asbestos fibres	
Surface treatment	2	Unsealed asbestos insulating board, or encapsulated lagging and sprays	
Asbestos type	2	Amphibole asbestos excluding crocidolite	

Table 4.20. *Priority assessment algorithm of the sample E-44*

Normal occupant activity		**Score: 3**	**Total score is 8**
Main type of activity in area	3	High levels of disturbance, (e.g. fire door with asbestos insulating board sheet in constant use)	
Likelihood of disturbance		**Score: 2.3**	
Location	3	Confined spaces	
Accessibility	2	Easily disturbed	
Extent/amount	2	>10 m^2 to ≤50 m^2 or >10 m to ≤50 m pipe run	
Human exposure potential		**Score: 0.7**	
Number of occupants	1	1 to 3	
Frequency of use of area	0	Infrequent	
Average time area is in use	1	>1 to <3 hours	
Maintenance activity		**Score: 2**	
Type of maintenance activity	3	High levels of disturbance (e.g. removing a number of asbestos insulating board ceiling tiles to replace a valve or for recabling)	
Frequency of maintenance activity	1	≤1 per year	

The equation of asbestos risk assessment is given below:

Material assessment score for each ACM		Priority assessment score for each ACM		Risk assessment score for each ACM
8	+	**8**	=	**16.5**

The calculated asbestos risk assessment, about 17, infers that the area is in Category B with a medium risk level. The selected sample (E-44) used in assessment is indicated in Figure 4.15.

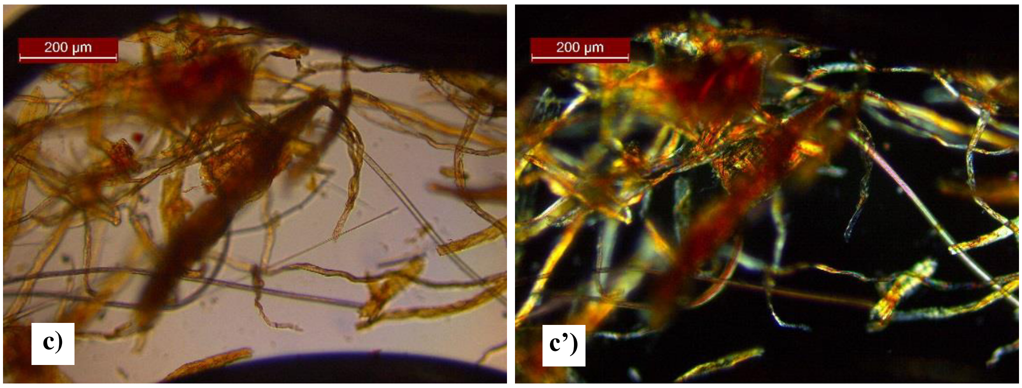


Figure 4.15. Macro to micro photographs of the s ample E-44; a) sample's general view b) SM view, c&c') PLM view

CHAPTER 5

RESULTS AND DISCUSSIONS

Whole buildings which are studied as a part of this thesis, were built between 1960 and 1980. These years are selected specifically for the use of asbestos in construction materials at that period. Although it is commonly accepted that in Turkey, materials containing asbestos are only used in buildings as insulation materials, it is not the case.

As a result, in this study, samples from walls which extensive masses in buildings (i.e. non-insulation material), are collected more than insulation and floor materials (Figure 5.1) in an attempt to clearly identify and demonstrate the presence asbestos in the wall materials. Different materials from walls as well as floor and insulation are sampled as much as possible in order to fully examine the possibility of presence of asbestos. In total, 150 samples are taken from 31 different items of wall, floor and insulation materials.

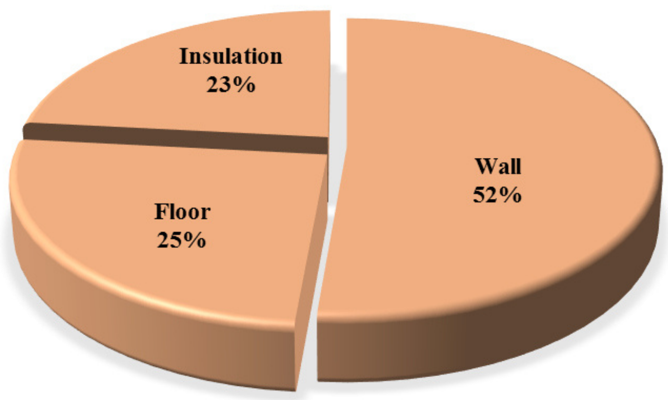


Figure 5.1. Distribution of the samples based on the construction materials

The number samples of which are collected, examined under PLM after steremicscopic observation, and detected for asbestos after a PLM study, are summarized in Table 5.1. The examination by stereomicroscope shows that not all the 150 samples contain fibrous material. Only 75 of the samples are interpreted to have fibrous material, which are further examined by PLM. While fibrous material in only 5 samples is not determined as asbestos by PLM, the resting samples (70) are interpreted to have asbestos. As expected, 97% of insulation materials contain asbestos minerals. 73.7% of the floor samples contain asbestos types. 18.2% of the wall samples, in general known as without asbestos, have asbestos.

Table 5.1. *Summary of sample numbers*

	Collected sample number	**PLM examined sample number**	**Asbestos-containing sample number**
WALL	77	17	14
FLOOR	38	24	22
INSULATION	35	34	34
TOTAL	***150***	***75***	***70***

The number of asbestos containing wall samples is not high compared to the other materials. The wall samples, however, have all types of asbestos including amosite. As far as the wall mass in a building is considered, collecting representative samples from wall and even floor should not be ignored besides pipe insulations.

All six types of asbestos are observed in the studies on three main construction materials. In fact, when evaluated according to the buildings, Building-C, Building-D and Building-E have all asbestos types. The other buildings, which are Building-A and Building-B, have five and four asbestos type, respectively.

Chrysotile is the most common asbestos type amongst the total samples. The percentage of Chrysotile in 70 samples is 56.6, and the other types including amosite and crocidolite are observed in different percentages (Figure 5.2). In some of the samples, only one type is detected, whereas in others, more than one type of asbestos is defined. Mixture of asbestos types in wall, floor and insulation materials could cause the exposure to be extensive if there is any huge repair or demolishing processes in the area.

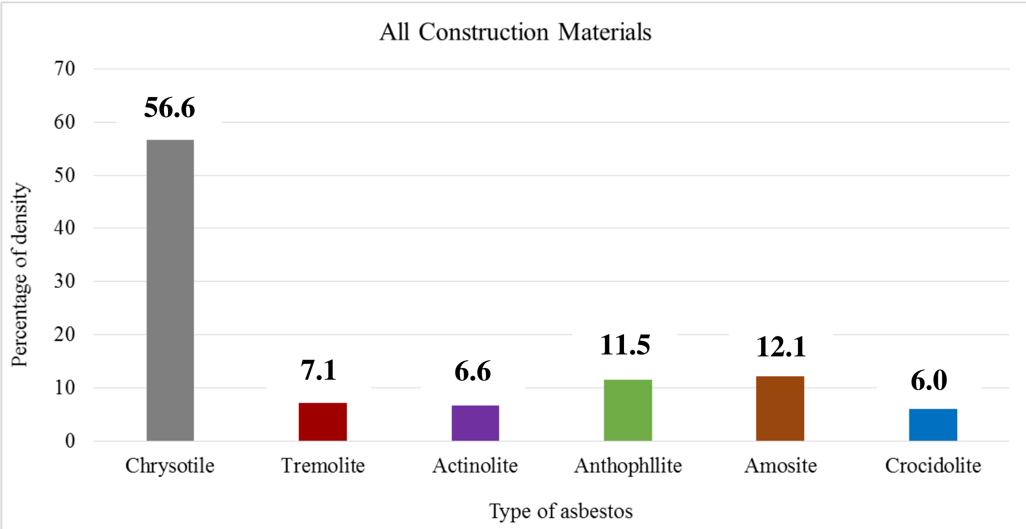


Figure 5.2. Density of asbestos types in the samples with fibrous content

The wall samples with asbestos, mostly only have one type of asbestos (Table 5.2). However, 21.4 percentile that are examples of scratch coat and exposed concrete has two type of asbestos. 40.9% of the floor samples contain two or three types of asbestos in the same sample, in addition to the only one asbestos type in a sample (Table 5.2). These samples are vinyl floor covering, ceramic tile, concrete tile, concrete and textile-based floor covering. 58.9% of the insulation samples constitute two, three and four asbestos types in the same sample, which are from heat changer pipe insulation, insulating paper, heat resistant rope, pipe insulation and melamine coated chipboard (Table 5.2).

Table 5.2. *Containing of asbestos types in the samples*

	Containing one asbestos type	**Containing two asbestos type**	**Containing three asbestos type**	**Containing four asbestos type**
WALL (14 samples)	11	3	-	-
FLOOR (22 samples)	13	5	4	-
INSULATION (34 samples)	14	14	4	2
TOTAL	***38***	***22***	***8***	***2***

Asbestos risk assessment is applied to the representative areas in the pilot buildings. The results of the assessments vary due to the scoring system in the tables (Table 4.3, Table 4.4, Table 4.7, Table 4.8, Table 4.11, Table 4.12, Table 4.15, Table 4.16, Table 4.19 and Table 4.20). The calculated scores are controlled both by the material and present conditions of the area. Correct identification of asbestos is quite important for the scoring part because iron rich varieties like amosite are more hazardous to health-related problems. Moreover, the locations of the materials are analyzed for proper scoring.

If ACM is well maintained, the exposure of asbestos due to activation is less, and it is unlikely that observing cases of cancer in the employees which work since many times in the locations (Whysner, 1994). When asbestos risk assessment is applied, one of the most important steps is the deformation condition of asbestos-containing materials. If there is a deformed ACM, asbestos activation from the friable part of the material may occur and concentration of asbestos fibers in air can be recorded. According to regulations in Europe and Turkey, concentration of asbestos must be a maximum of 0.1 fiber/cm^3 in the air in a workplace for the duration of 8 hours (MLSS, 2013).

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

All of the public buildings designated as pilot zones were constructed between 1960 and 1980, the period when asbestos usage was highly favored. Employees who work in these public buildings, chosen for the thesis study, do not work directly with asbestos material.

The public buildings with large number of employees which were chosen for this study, are damaged by various deformations due to the clayey ground they inhabit. There is a high possibility of activation of asbestos construction material due to cracks of various dimensions caused by these deformations, however, it is still under discussion. There is a need of periodic renovations in these selected public buildings, and this it affects the white-collar worker as well as maintenance and repair crew. Additionally, the effect of asbestos material used in heating pipes with the purpose of heat isolation is pinpointed, within the framework of occupational health, maintenance and repairing.

Asbestos existence is one of the most critical point for maintenance and repair services or destruction. In this study, existence and types of asbestos are examined in the construction materials. The identification of asbestos is conducted by mineralogical-petrographical studies using light microscopy methods such as stereo microscope and polarized light microscope.

The buildings selected were constructed in the years when asbestos was used intensively. Contrary to common belief, the material was not only used in pipe insulations, but also in representative samples from all different building materials that are collected. After examination steps, six type of asbestos which are Chrysotile, Tremolite, Actinolite, Anthophyllite, Amostite and Crocidolite are identified with the various rate of asbestos content within the construction materials. Chrysotile is the most abundant variety in wall, floor and insulation materials from all of the studied buildings. It is important to emphasize the presence of Amosite and Crocidolite in almost all samples, which are the most dangerous varieties of asbestos minerals.

The results of this study reveal that there are some important conditions which should be adressed which are;

i. In old buildings, not only insulation materials, but also the other types of construction materials such as wall and floor, contain asbestos.
ii. Glass wool, which is used instead of asbestos-containing materials for insulation purposes, could have been mixed with asbestos. Therefore, it should not be assumed as safe.
iii. Correct identification of asbestos content of the construction materials is important for both occupational health and public health.
iv. Risk assessment of asbestos is meaningful, only if the Material Assessment Algorithm and Priority Assessment Algorithm are applied together. Otherwise, the result of the assessment would be inadequate.

Even though asbestos production is not an issue anymore, nowadays in many countries urban transformation concept brings up the asbestos-related diseases to the agenda again. The four items mentioned above signifies the results of this thesis in order to prevent health risks within both occupational and public health issues.

6.2. Recommendations

Important steps have been taken in the field of prevention of asbestos usage as construction material, with several legal regulations enacted both in developed and developing countries alike. At this point, the demolished buildings are examined with relation to the public health and for the occupational health of the workers who were employed during the demolition process.

However, besides the consideration during the demolition process, if only maintenance-repair of the building is required, the implementation of regulations must be considered important for employees' health. Also, asbestos risk assessment must be done before the maintenance-repair or the demolition of buildings which were constructed before 2010 in Turkey.

This study refers to the asbestos inventory of the pilot buildings. Similar studies must be conducted with subsidy in each public building in order to prepare an asbestos map of the building. It could be of great use for preventing asbestos-related diseases because that inventory helps to take the necessary precautions. Moreover, concentration of the asbestos fibers in the air should be determined if there is an activation of the asbestos due to material deformation.

Although other evaluations in the pilot buildings are out of the scope of this thesis, some other recommendations, which are important in terms of health & safety, are given as a result of the observations. The additional recommendations are related to working environments of employees. According to the observations made in different workplaces during the investigation and sampling steps of this study and one-to-one conversations with both blue-collar and white-collar employees, it is deduced that the poor physical conditions of workplaces affect directly and negatively the employees. Bad physical conditions infer any windowless and small rooms, damp or ragged offices. These workplaces are selected compulsorily due to lack of any suitable work places in the buildings, and some of them are not cured due to financial difficulties.

According to Sundstrom (1986), air quality, lightening, temperature and humidity are necessary components for a good workplace. Especially daylight is one of the most crucial aspect which is directly related to the mental health of employees. Moreover, on a research conducted about the wellbeing of employees, it is stated that physical conditions of the workplaces have a certain influence on overall productivity and efficiency (Paradise *et al.*, 2018).

In addition, it should be emphasised that some technicians are settled in heat changer rooms, again due to the physical inadequacies of the pilot buildings. This circumstance may increase the exposure of asbestos for the settled employees, because the pipes are wrapped with a type of glass wool which contain asbestos in different densities. Therefore, the fact that technicans are being exposed to the asbestos during their routine shift create critical conditions for them and immediate measures should be taken.

For the future studies as successive to this thesis, the recommendations are as follows:

i. In addition to the bulk sampling, the air sampling techniques can be implemented in areas with the most asbestos activation.
ii. Further mineralogical analyses by XRD and SEM-EDX should be applied to support the petrographic analysis for identification of asbestos content and to designate the percentage of asbestos density of the material sample itself.

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