Treatment of the Wooden Trunks in the Ceiling of the Burial Shaft of the Step Pyramid in Saqqara, Egypt

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[Abstract]

Saqqara is one of the most famous archaeological sites in Egypt and all over the world. It was the main necropolis of Memphis which was the capital of Egypt for the most part of the Old Kingdom period. Saqqara is also famous for the Step Pyramid which is the oldest stone structure in ancient Egypt. It was built by king Djoser who was the first king in the Third Dynasty. It is thought that the south entrance of the Step Pyramid was opened during the Saite period. During that period, a lot of restoration work was done to many places in Saqqara, one of whose places was the Step Pyramid, especially the south entrance, when they saw that there were cracks in the bedrock ceiling, that some limestone columns were used to support it. It seems that the ceiling of the burial shaft had a problem since that time. So, some wooden trunks were used to support the ceiling, especially in the places where there was a collapse. Those trunks were in bad condition, because they were affected by deterioration factors especially the brown rotten that caused the wood to be turned into cubes in different sizes. It is known that the ancient Egyptians used both local and imported wood, especially wood that was imported from Lebanon. So, it was important to identify the wood species to indicate if it was local or imported. Transmitted light optical microscope was used to identify the wood species. It is indicated that the species is Acacia Nilotica which has been common in Egypt from ancient times till now. There were deterioration products that could be seen on the wooden trunks such as cracks in different sizes and different depths, wood turned into cubes in different sizes. And then, and the surface of the wood was fragile and squishy, and some parts of the wooden trunks were covered with mortar that used for restoration in the Saite period or for supporting the ceiling during the current restoration project. Restoration work was done through three main steps. First, cleaning was done mechanically and chemically. Consolidation by using Nano cellulose and Plexisol P550, filling by using cotton injected with Paraloid B72 20% and Microballoon. FTIR analysis was done after using Nano cellulose and it indicated the percentage of cellulose in the wood was increased after using Nano cellulose for consolidation.

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1 Introduction

Saqqara is one of the most famous heritage sites all over the world. It is located to the west bank of the Nile south of Cairo the capital of Egypt. It is a part of Memphis necropolis which extends in the western desert about 80km from north to south, and it was the main necropolis of Memphis which was the capital of ancient Egypt during the Old Kingdom and the religious capital all over the ancient Egyptian history (Saad, 1941-1945). Saqqara is considered as the encyclopedia of the Egyptian history and art because it contains monuments and antiquities from different ages (since the beginning of the historical ages to the Coptic period (Mounir Basta, 1977). Its religious significance refers to Sokar, the graveyard god, from which the name of Saqqara is derived (Hawas, 2010). While the Arabic historical stories say that the word "Saqqara" is a name of an Arab Bedouin tribe who came and settled in the place of the village of Saqqara now in the medieval period (Bosner, 1994). The UNESCO considered Djoser pyramid and its funerary complex as a world heritage site in 1979. The Step Pyramid was built to be the royal tomb of king Djoser, the founder of the Third Dynasty in the 27th century BC. This pyramid was built by Imhotep, considered the first architect in the world and the minister of king Djoser. During the first and the second dynasties, the Egyptian architecture depended primarily upon mud and reeds. Imhotep was the first one to use stones and as a result, the Saqqara pyramid was considered the first stone architectural building across the ancient world. There was a great uprising in Egypt during the Saite period. Ancient Egyptians during that time tried to understand their ancestors' civilization. So they opened the Step Pyramid and made restoration work and of course they were influenced by the funeral architecture from king Djoser's complex.

2 Materials and Methods

To perform conservation and restoration work, optical digital microscope was used to investigate the state of wood before, during and after treatment. Transmitted light optical microscope equipped with an (OPTIKA B 9) digital camera was used to identify the wood species. Thin sections were obtained in the three principal anatomical directions: transverse (TS), tangential (TLS) and radial (RLS). The observation and description of the anatomical features for the samples were based on wood anatomy atlases [1-3]. FTIR analysis was done after using Nano cellulose to indicate the percentage of cellulose in the wood before and after using Nano cellulose for consolidation. A mixture of Ethanol and distilled water 3-1 was used for chemical cleaning. Plexisol P550 3, 5, 7% was used for consolidation. Nano cellulose 1% in Klucel G 0.5% was used to increase the percentage of cellulose in the ancient wood. Micro balloon with suitable color mixed by using Paraloid B72 20% was used for filling.

3 The Step Pyramid

The Step Pyramid is the most ancient stone building in Egypt. It was built by the first architect in the world Imhotep to be the royal tomb of king Djoser the first king in the Third Dynasty. The base of the pyramid is about 140m from east to west and 118m from north to south. The height of the pyramid is about 60m. There are three entrances, the original one is from the north, one from the south and the last from the east. The architectural studies performed on the Step Pyramid has proved that its first design of it was one mastaba, then there were four additions made it reach to be six steps (Basta, 1978)(Helen & Richard, 1963), all the six mastabas being built horizontally. They're not equal in height or in the size, of course. They are about 60m high (Basta, 1978). The pyramid was cased by polished limestone. This layer was lost except a few stones at the bottom of the eastern and southern facades. There are five levels of galleries underneath the pyramid. They are about 6km long. There are elven shafts under the casing of the eastern façade. The burial shaft is about 28m deep and has the shape of a square about 7 x 7m and 10 x 10m near the bottom. The granite burial chamber is about 3.5 x 5.8 x 3.5m and there are some marks on the granite blocks, which may mean numbering. There are alabaster sarcophaguses in the fifth gallery that may be for the princesses. The ceiling of the burial shaft was so collapsed that a block fell down from time to time. It was necessary to start a restoration and conservation project to preserve all the pyramid, especially the ceiling of the burial shaft. For that reason, a big project was done by an English company to save the ceiling, however it was also necessary to treat the wooden trunks that were in bad condition. In fact, those trunks have lost their job as supporter, and it was necessary to treat them and keep them in their original places.

Photo 1 South façade of the Step Pyramid (after restoration) where there is the south entrance

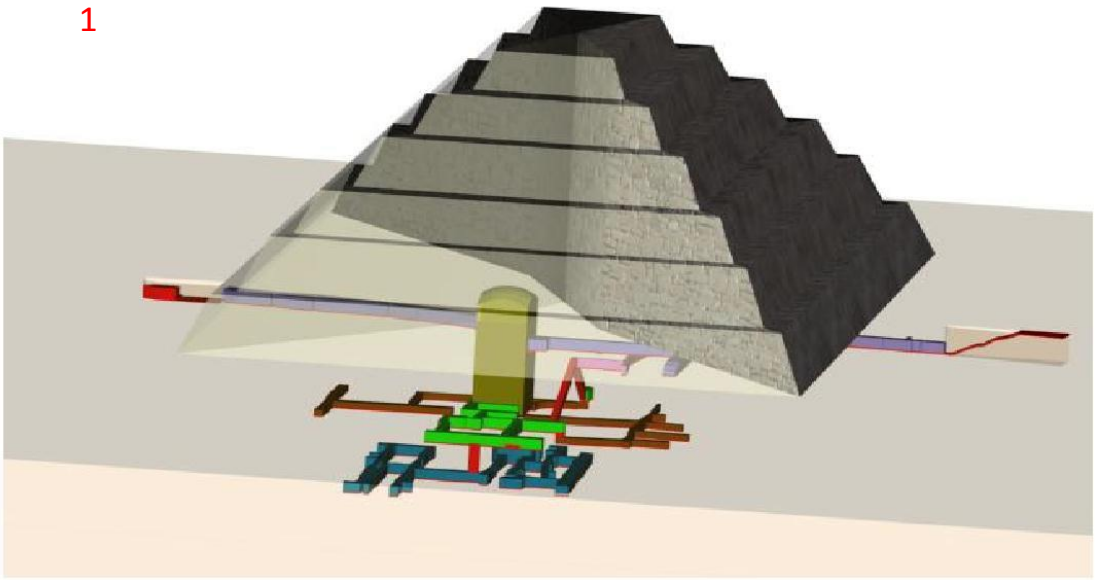

Fig 1 3D of the Step Pyramid, the burial shaft and the underground levels

4 Wooden Trunks in the Ceiling

It is thought that the south entrance of the Step Pyramid was opened during the Saite period. During that period, some restoration work was done to the Step Pyramid, especially the entrance where some limestone columns were used to support the cracked ceiling. It seemed that the ceiling had a problem since that time. So, some wooden trunks were used to support the ceiling especially in the places which were collapsed. Those pieces of the wooden trunks are in different sizes, the longest of which is located on the western side under the ceiling, about 6.54m long. The second piece is located on the southern side under the ceiling. It is about 4.78m long. There are two small pieces in the southern side. One is located underneath the ceiling blocks from west to east, about 2.82 m long. The other is smaller, it is about 1.71m long. The eastern side has small pieces that are thrusted in the ceiling. Although they were longer before, they might be broken because of falling blocks. All those trunks were in bad condition, and they were so fragile that some small pieces might separate and fallen. The effect of brown rotten could be seen in all trunks, and there are different sized cracks could be seen in all trunks.

4.1 Identification of Wood Species

The ancient Egyptians used different kinds of wood for different reasons from pre-history; wood was used to make coffins, statues, and false doors etc. They also imported good kinds of wood to be used for making big ships and luxurious furniture. Although it is obvious that the wood used to support the ceiling of the burial shaft was a local species, it was necessary to identify it. Transmitted light (OPTIKA MICROSCOPY, (ITALY) equipped with an (OPTIKA B 9) digital camera was used to identify the wood species. Thin sections were obtained in the three principal anatomical directions: transverse (TS), tangential (TLS) and radial (RLS). The observation and description of the anatomical features for the samples were based on wood anatomy atlases [1-3].

4.2 Results and Discussion

Microscopic identification for thin sections indicated that the wooden trunks that used to support the ceiling of the burial shaft in the Step Pyramid were Acacia nilotica. It is a Perennial shrub or tree which grows in different parts of the world. In Africa, it is found in a lot of countries such as Egypt, Algeria, Angola, Botswana and Ethiopia. Its height ranges between 2.5–10m tall. The wood from that tree has been used since prehistory because it is strong, heavy and durable. In Sudan, it is used as railway sleepers. It is also used for heavy construction as well as tool handles and carts (Internetttp://www.weeds.crc.org.au).

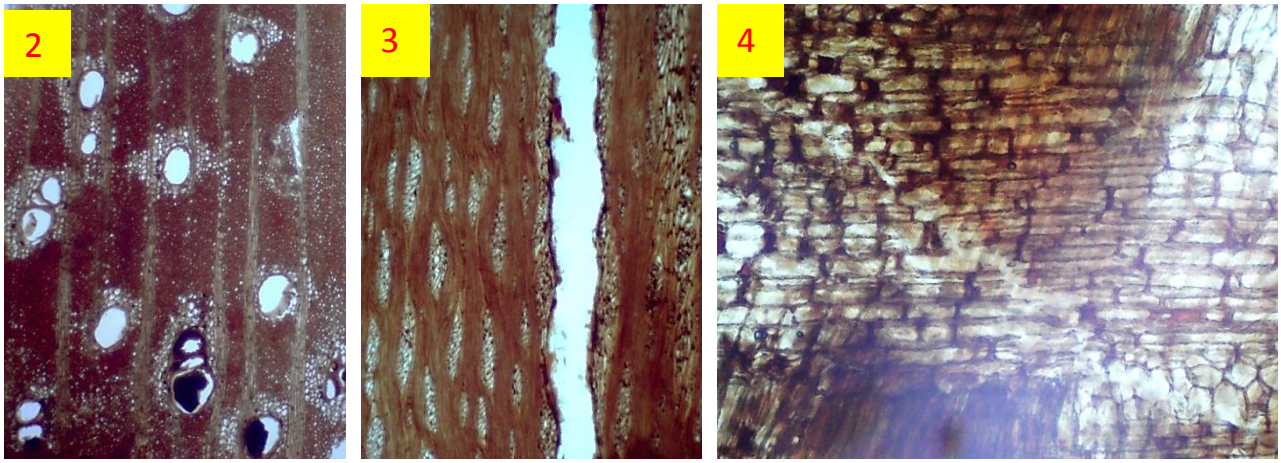

Photo 2-4 micrographic showing the diagnostic characteristics used to identify the wood of the trunks that is Acacia nilotica

5 Deterioration Factors that Affected the Wooden Trunks

Wood is one of the organic materials that are affected by different deterioration factors, and those deterioration factors lead to different kinds of degradation. Degradation of wood could start in the local environment.

Fungi and insects decay affects living trees in the forest floor or wood in service (Zabel and Morrell, 1992). In addition to causing economic losses, fungi play an important role in recycling elements in the forest floor (Boddy and Watkinson, 1995). In our case, those trunks which might be cut two thousands and six hundred years ago (at least), no one knows if there were any fungi or insects affecting them during the time of using. However, it is thought that the ancient Egyptians, who used those trunks for supporting the ceiling, could not chose infected wood. So, it is thought that the degradation of the trunks started after using them in the ceiling of the burial shaft. There are three main deterioration factors that might affect the wood.

5.1 Brown Rot Fungi

This kind of fungi is classified from the Division Basidiomycota. It has its name because of the brown product of wood that is caused by this fungus. This fungus feeds on cellulose and hemicellulose, not on Lignin. The enzymes that are produced by this fungus cause degradation of wood as they cause vertical cracks and turning wood into different sized cubes colored brown to black. Finally, wood turns into brown or black powder. That could be seen in all the wooden trunks in the burial shaft, especially in the longest one in the western side.

5.2 Temperature and Relative Humidity

Most fungi can grow in humid atmosphere, as the more humid the surroundings are the more suitable for

fungi growth. Concerning temperature, the most suitable temperature for fungi growth is between 25-35^{C}. From the records of temperature and relative humidity inside the burial chamber indicate that the levels of relative humidity range between 38-62% and temperature degrees range between 23-27^{C}. So it is obvious that weather conditions inside the burial shaft are suitable for the growth of organisms such as the brown rot fungi.

5.3 Deterioration Forms on the Wooden Trunks

There were some deterioration products that can be seen on the wooden trunks. All the forms were produced because of the deterioration factors that worked all together.

- There were some remains of mortar that covered some places of all the trunks. That mortar was used during the work of supporting the ceiling that was carried by current project. Because the mortar was lime based mortar, so it caused some places to be whitish. There were some traces of light pink color that could be used by ancient Egyptians during restoration work in the Saite time.
- there were remains of soot that might be produced by the fire which was used by ancient Egyptians during restoration work in the Saite time.
- the surface of the trunks turned into cubes in different sizes because of the brown rot fungus.

6 Treatment of the Trunks

Although all the trunks lost the ability to support the ceiling as they were used for, it was necessary to preserve them and keep them in their original places as they are a part of the place history. To start restoration work of the wooden trunks had to be delayed until all restoration works in the ceiling of the burial shaft was completed.

6.1 Cleaning

Cleaning is the first treatment process that is usually done to remove dirt that misshape the surface of the object and make it be ready to receive consolidants. Mechanical cleaning was done to remove dust and remains of mortar. It was necessary to be careful during removing the remains of the mortar because they were stuck to the surface of the wood firmly. It was necessary to use metal spatulas and scalpels besides using brushes.

Chemical cleaning was also important to clean and remove the remains of the mortar that were very tiny and inserted in the pores of the wood. It was also necessary not to use much water on the surface of the wood. So a mixture of ethanol and water 3-1 was used and gave a good result.

6.2 Consolidation

The second step of treatment was consolidation. As it was mentioned that wood was fragile and spongy, it needed to be consolidated more than one time and with high concentration. Although Paraloid B72 is one of the most famous and effective consolidants, it could not be used in high concentration because it could cause the surface of the wood to be darker and shiny. It was decided to use Plexisol P550 solved in toluene as a consolidant. It was necessary to start with low concentration, then to higher concentration, which allows the consolidant to penetrate into the pores of the wood. Three concentrations were used, first 3% then 5% and finally 7% that led the wood to be harder than before.

6.3 Filling

The surface of the wood turned into separated cubes that fell one by one from time to time. It was necessary to fill among those cubes to fix them. However, when those cubes were touched anyway, they loosed off their places and fell down. It was decided to use a kind of net to fill among the cubes, on condition that the net was flexible to twist among all the cracks. So, it was decided to make that net by inserting cotton among the cracks, then it was injected by using Paraloid B72 20% to harden the cotton and make it like a net that links among the cubes. Filling with cotton was about 0.5cm under the surface of the wood. After filling by using cotton and Paraloid B72 20%, it was necessary to fill the cotton with a suitable substance with a suitable color to match the color to the original wood. Microballoon was used mixed with a suitable dust color and Paraloid B72 15%. There are some advantage of using microballoon, because it is so soft that it could be controlled well during work. It is resistant to microbiology growth. It was mixed with Paraloid B72 20% and that made it reversible. First a sample was applied to be sure if it would match the color of the original wood, then it was applied all over the trunks. It was applied to be about 2-3 mm under the surface of the original wood level.

6.4 Consolidation

It is known that the brown rot affects the amount of cellulose in wood and that it makes wood weak and fragile. Therefore, it was necessary first to raise the amount of cellulose in the wood and second to strengthen the fragile wood by using a suitable consolidant. For raising the amount of cellulose in the wood of the trunks, a solution of Nano cellulose solved in 0.5% of Klucel G., whose solution was applied by using brushes. The most valuable merit of using Nano cellulose is that it can penetrate through the pores of wood and reach deeper inside the wood. Although Paraloid B72 is one of the most common consolidants that is used in organic and non-organic antiquities, it has some disadvantages especially when it is used in high concentrations. It causes the surface to be darker and shinier. It is decided to use Plexisol P550 solved in toluene in three different concentrations 3-5-7% to strengthen fragile wood. One of the most important advantage of Plexisol is that it doesn't cause the surface to be

darker or shiner. This is because it is always solved in Toluene which is less volatile than Acetone. The worst disadvantage of Toluene is that it is highly toxic and very bad to health.

7 Conclusion

The wooden trunks used to support the ceiling of the burial shaft were so fragile because of the brown rot. From the microscopic identification for thin sections, it is indicated that they were (Acacia nilotica). Cotton injected with Paraloid B72 20% was the best filling to connect among the cubes. Microballoon mixed with suitable color and Paraloid B72 20% was used to cover the cotton that was used in the filling. Plexisol in 3-5-7% concentrations was used for consolidation. Nano cellulose was used to requite the shortage of cellulose which was caused by the Brown rot.

Photo 5-9 Wood trunks before restoration

Photo 10-13 Deterioration forms on wood trunks

Photo 17-20 Mechanical and chemical cleaning

Photo 21-22 Filling among cracks by using cotton

Photo 23-26 Injection by using B72 20 to harden the cotton, consolidating wood by using Plexisol P550 3-5-7% and making a test of filling on the cotton by using microballoon with a suitable color mixed with B72 15%

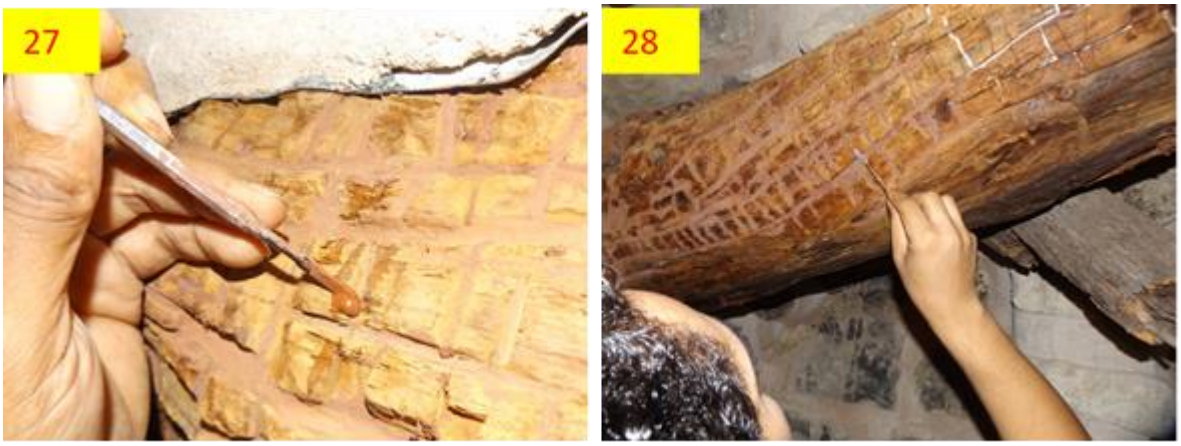

Photo 27-28 Filling on the cotton by using microballoon with a suitable color mixed with B72 15% after ensuring that the color of the filling matches the wood

Photo 29-31 Digital microscope of the surface of the wood after mechanical and chemical cleaning

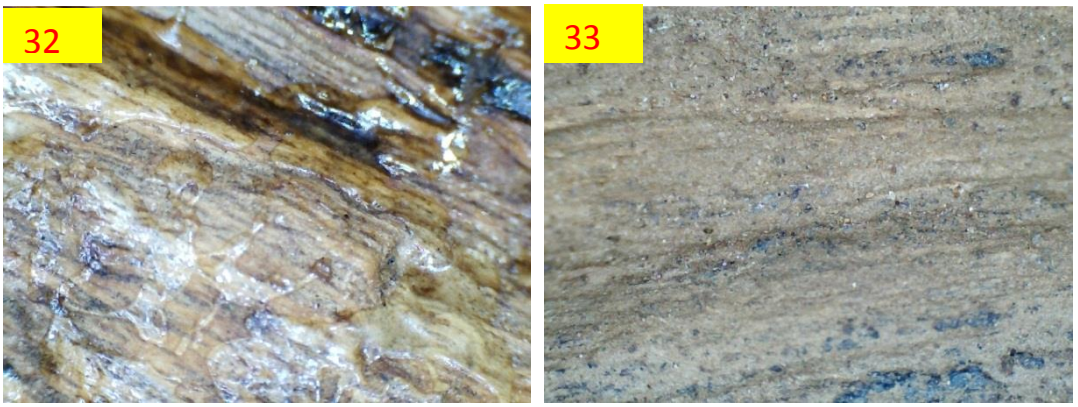

Photo 32-33 Digital microscope; 30 surface after consolidation by using Plexisol; 34 surface after consolidation and by using Nano Cellulose

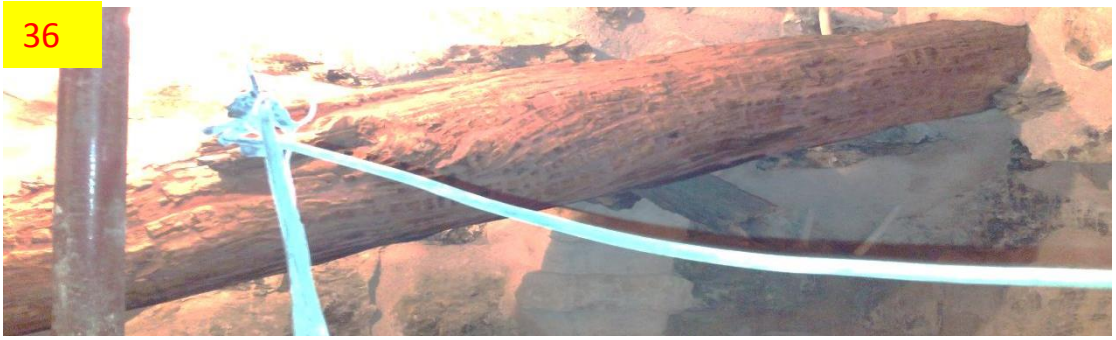

Photo 34-38 Digital microscope of the surface of the wood trunks after restoration work

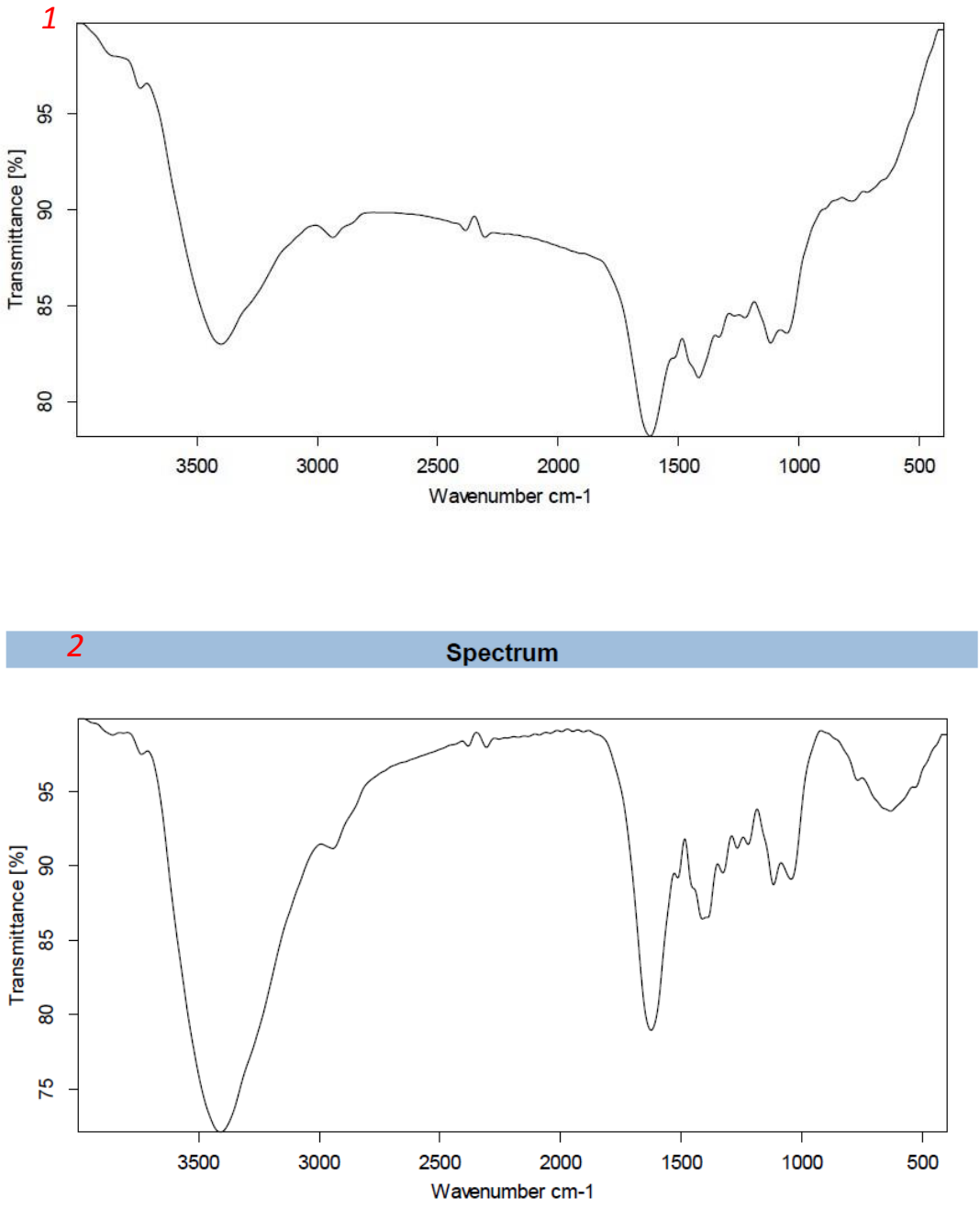

Chart 1-2 FTIR spectra showing how the peak of cellulose became higher after using Nano cellulose for consolidation

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