The tower of pisa economics essay

The Tower of Pisa has been a tower that has been of a great note to people for more than five hundred years. A great feature of the tower comes from the large tilt that can be found in it. The leaning Tower of Pisa is one that has been reviewed for generations and has had many processes handled on it. The tower has dealt with a difficult construction process. Much of the process was delayed to the point where it took around two hundred years just to get the tower constructed. The poor foundation and the lack of control in the construction process did not help either. Many changes have been made to the tower over the years. These include the use of lead ingots and fluid underneath the tower to help with fixing the problem. A permanent solution that involves repurposing the soil has been tossed around as well. The wind conditions around the tower have impacted the way how it leans. The wind has created plenty of pressure on the tower over time. Also, the foundation is a major factor as to why the tower is so poorly built and tilted. This is due to the poor sand and silt conditions of the area. This is a major factor in that it has caused the pressure on one end of the tower to be greater than it is on the other end. There is also the consideration that the foundation is incredibly shallow and is not as deep as it should be for a tower of its substantial height. However, the problem that the Tower of Pisa faces today can still be one that may be corrected. This comes from how one tower in the Netherlands has been impacted in a similar way but has been fixed.

1. Introduction

The Tower of Pisa in the Italian city of Pisa has been a great part of interest to people for generations. A great reason for this comes from how it is a tower that has been leaning on its side for centuries. This tower has dealt

with some substantial concerns over its construction since it was first built. Over the years it has become a great building for people to review.

It is not only a big tower but it is also very heavy. The tower is about fourteen thousand tonnes in weight. It is also close to sixty meters in height (Nakamura, et al. 1999: 31). This means that it is something that is very easy to notice. The tilt that is found here will also be very easy to see thanks to how high up and large this building is. In fact, the size of the building is something that has become a critical feature to see with regards to trying to get the tower to stay upright.

This review will take a look at many of the things that has influenced the Tower of Pisa with regards to how the tower has fallen as far as it has and is still intact. This includes looking into how the tower fell and how reinforcements have been used to keep it up as well as possible. A good look at other factors that relate to the Tower of Pisa and why it is in its current condition will also be considered.

These are all factors that will be shown to see just how this amazing marvel is still around to this day. The Leaning Tower of Pisa is a truly interesting building for anyone to study when it comes to taking a look at how a building is built and how it operates.

It is important to take a look at some things with regards to the Tower of Pisa. These include the reasons as to why the tower has begun to fall as much as it has been. Details on all of the processes that have been handled for getting the tower protected through reinforcements should also be reviewed. These considerations and more are all critical to see with regards

to working to keep the tower from falling. This is so the tower can be safe and will not pose a risk to anyone while at the same time being a historic site for people from all over the world to visit.

2. 1 Why did the Tower begin to fall?

The Tower of Pisa was first built starting in August of 1173. However, the progress on the construction of the tower stopped about five years later. This was due to economic and political concerns around the city of Pisa. The construction did not continue until 1272. (Jamiolkowski 2001: 17) It is widely believed that the massive delay in the process of getting the tower built might have been a substantial factor as to why the tower has begun to fall as much as it has been.

The soil in the foundation for the tower began to become resistant to the foundation for the tower during this period of dormancy. Consolidation, which is a condition where the soil in an area declines in its volume, occurred in this case. This would become even worse in 1278 when construction was halted for a second time. (Jamiolkowski 2001: 17)

The Tower of Pisa began to fall between this time and the actual completion of the tower in 1350. A big reason for this came from how the foundation soils were too weak at the time. It had become very difficult for the soil to support the tower in a proper manner.

There is also the factor of how the tower is dealing with a greater amount of pressure on one side versus the other. The tower has a substantially higher pressure level on the south end of the tower over the northern end

(Terracina 1962: 337). This is due to the way how the tower is slanting towards the southern end. This is produced predominantly by the way how the soil and the foundation in the area have been influenced dramatically to where the tower is substantially slanted.

The fact that the tower is dealing with a greater level of pressure on this part has created the concern that the tower needs to work with some support and reinforcement that is going to help with keeping the tower supported on its northern end.

Finding a way to increase the pressure on the north is the key to trying to keep the tower from collapsing. This is why there are a number of different reinforcements that are currently being used as a means of attempting to save the tower from any danger in the future.

A big feature of the tower was that even though it was evident that it was beginning to tilt, the people who were responsible for building the tower did not seem to pay attention to what was going on. This might have caused the tilt on the tower to become even greater than it already was.

An example of this comes from the way how the construction was altered to adjust to the tilt that was being found. The areas of the tower from the fourth cornice up to the top were not rectilinear like it was at the bottom areas. A big part of this can be seen in the belfry. The north side of the belfry has four steps on its side. The south side, on the other hand, has six steps on it (Jamiolkowski 2001: 18).

This is something that might suggest that the people who were responsible for building the tower might have ignored the foundation concerns of the tower. They might have tried to simply get the tower built up simply because of how long it had taken to get it ready the first time around. Therefore, the process for getting the tower built was more than likely made without any concerns about the build of the tower in mind. This is a great ready as to why checking the foundation of the building under construction is such a critical thing to do when getting a construction project taken care of.

There is also the consideration that involves the soil that is used underneath the area. The closest soils to the sea level for the tower are sandy and clay silts. These are very loose soils that have very few layers to them. This may be an influencing factor as to why the tower is as unstable as it is and why it has fallen so much.

The upper sand underneath these silts features grey sand alongside clay layers. Several clay applications can be found underneath the tower. However, the tower does go into have a very deep foundation (Burland, et al. 1998: 94). The foundation will be covered in a later part in this report.

The amount of pressure that is being imposed onto the southern part of the tower¿½¿½s base is substantially higher than that of what is being used on the northern part. A big part of this comes from how the tower is going to feature a deeper impression into the ground. (Nakamura, et al 1999: 32). This impact is a big reason as to why the tower is falling in as much as it has been.

The exact level of the tilt that is found on the tower is especially dramatic. The tower is tilting to the south at a rate of about 5. 227 meters off of the center (Nakamura, et al 1999: 32). This is a massive tilt that may be a risk for anyone to see and could end up being harmful.

In fact, reports from about two hundred years ago suggest that the tilt was massive. A report from surveyors in 1817 states that the tower was tilting at a rate of about five degrees at the time that the measurement with taken (Jamiolkowski 2001: 19). This is a massive risk that might end up suggesting how even back then people were concerned about the tower.

There was one massive change that occurred to the tower in the nineteenth century. The Catino around the area was excavated by Alessandro Gherardesca in 1838. This excavation ended up influencing the ground water table because it went well beyond that area. This caused the area to fill up with water.

This impact was treated in 1935. The foundation was treated with a large cement application to correct the problem.

This was used to help with keeping water from getting into the area and possibly influencing the way how the tower leans. It ended up helping to keep water out of the way but it still did not do all that much to try and keep the tower from suffering from the incline that it is dealing with to this day (Jamiolkowski 2001: 18).

All of these features are big ones to see for the tower. The fact that the tower was built so long ago is a factor that might end up influencing the way

how the tower is going to be organized and handled with different plans in mind. Therefore, the most delicate care is going to have to be handled in order to ensure that the plan will work out properly.

2. 2 What reinforcements are being used on the Tower?

The goal of treating the Tower of Pisa involves working to ensure that the tower is not going to fall over at any time in the future. A vital part of the reinforcements is that the shearing strength of the tower should be kept to a value of zero. The shearing strength refers to the maximum amount of stress that can be handled without suffering from any damages (Ranzini 2001: 647).

A review in 1911 was used to determine that the two sides of the tower were changing dramatically in terms of how they were moving around. The tower was found to not only have its southern area falling but also its northern area rising. Therefore, a proposal was sent out to where the tower could have a load attached onto the northern part of the foundation masonry. It was considered to be a way to help with keeping the natural tilt of the building from being too severe. It would be used as a counteraction against the tilting motion (Burland, et al 1998: 96).

This 1911 proposal has been reviewed on a number of occasions. A full review has found that the tower is able to handle a maximum amount of fourteen hundred tons on weight on the northern end of the foundation masonry. This will be used to help with supporting the rotation of the tower (Burland, et al 1998: 96).

One such plan to get this to work was handled between 1993 and 1994. A series of lead ingots that are about ten tonnes in weight each were used along the build of the tower. The load would end up being about seven hundred tonnes in weight (Jamiolkowski 2001: 26). This is only a fraction of the weight that was proposed the first time around. However, it may be good enough to where it can be durable.

Also, a concrete ring has been posted onto the base of the tower. This is a ring that was installed alongside the lead ingots. This ring was planned in the early 1990s as a means of helping to support the tower on a temporary basis. The ring would be made with a series of lead ingots used to help with supporting the tower. The tower was consistently reviewed during the entire process with many things in mind. These include checks on all survey stations around the walls of the tower and external leveling of benchmarks around the build of the tower.

The full process has helped to where the tower is at a greater inclination. There is a greater tilt towards the northern end of the tower. This is used to support the tower in order to ensure that there will not be any problems associated with it (Burland, et al 1998: 97).

The excavation plan here was ended in 2001. The support beam and the lead ingots that were mentioned here were removed at this time. A majority of the soil that was removed in the process came on the northern end of the tower (Jamiolkowski 2001: 31).

The greater concern is that an increase in the stress on the tower is going to end up causing the tower to be put at risk of suffering from more damages.

The soil in the tower can end up dealing with problems that relate to the consolidation of the soil in the area. Stresses can cause consolidation to occur in the area (Ranzini 2001: 647). This may end up influencing the ability of the tower to stay upright due to how weak soil that has consolidated is going to be. The fact that the volume will be lower for the soil in this case is going to be a critical part of the process.

One big study that was made in the late twentieth century found that some inserts can be used in the tower to protect it. Cement grouts are being offered as materials that can be injected into the tower alongside steel reinforcement bars (Jamiolkowski 2001: 25).

A big part of the process for getting the tower to be supported involves the use of ground anchors. One such idea for anchors involves the use of ten anchors that will be cemented into the ground. Each anchor will be supported through steel cables that will be cemented at a depth that will help to keep all of the wires tight inside the ground with no disruptions.

The steel cables for these ground anchors would be cemented into the ground through the sands at a depth of about forty-five meters in depth. All lead ingots used on the tower would be removed over a period of time to support this process. This will work as long as the anchors are all properly tightened and tensioned down to where they will properly work. This is considered by people to have a solution that will involve supporting the tower at greater rates with regards to the pressures used on them over other things. The problem with this option is that while it is something that may be

more durable, it is only a temporary solution to the problem (Jamiolkowski 2001: 27).

An interesting idea that has been passed around for supporting the tower involves the use of getting a viscous fluid into the soil. This is a type of fluid that would be less likely to move around when pressures are felt on it and will be able to retain its shape for a longer period of time than something else.

The viscous fluid could be used as a means of providing a surface that is going to feature a reduced level of pressure on it (Ranzini, 2001: 647). This will be used to keep the tower from being damaged and to keep the tower from dealing with any friction in the area. It is something that is being considered with the protection of the tower in mind.

While it is true that this has been very effective there are concerns about how permanent stabilization can occur. Some ideas for permanent stabilization have been tossed around. A big part of permanent stabilization involves how the tower is going to have its incline reduced by half a degree in intensity.

One strategy that has been proposed for permanently fixing the problem is the use of soil extraction. This is a plan that involves the use of removing small parts of soil from underneath the northern part of the building¿½¿½s foundation. This will then create a change in the surface tilt. This is a procedure that will be used to help with causing the tower to be less likely to tilt as greatly as it has been. This is a strategy that is especially being promoted due to how it has been used in Mexico City on a number of

occasions and has been successful most of the time (Burland, et al 1998: 97).

Interestingly enough the removal of soil has worked in the excavation process in 2001 that was mentioned earlier. Additional excavation processes may end up being just as durable and effective for all processes to handle. This is critical for anyone to take a look at when trying to get the tower to become properly stabilized. This is needed with the protection of the tower in mind.

There is a critical part of the measurements that are being used to help with getting this problem corrected. This relates to the measurement that is being used for determining if the adjustments to the tower have been successful.

The tower will be measured with regards to whether or not it has dealt with any reduced pressures. A proper type of procedure will be one that is going to reduce the stresses that are created by a tilt by about fifty percent (Ranzini 2001: 648). This is used primary with the intention of being sure that the tower is not going to be harmed by anything. This is especially critical to see with regards to the way how the soil in the ground could end up being compressed by the pressure of the tower.

2. 3 Wind actions

A notable feature of the Tower of Pisa is that the winds that are imposed on the tower on a regular basis work in unique ways. Wind actions around the tower have substantially influenced the ways how the tower is slanted. The

wind actions work with different standards with many of them being ones that have been influenced by the way how the tower is slanted.

A notable feature of the winds that are being found around the tower is that they are more consistent in the east-north-east and west-south-west directions. Also, higher gusts of wind tend to work in all directions and do not necessarily impact specific sections of the tower only. The ENE and WSW directions are the ones that will be influenced the most. (Solari, et al 1998: 4)

Interestingly enough the lowest wind speeds that are found on the tower come from the northwestern end of the tower. This may have been caused by the way how the tower is slanted to where it is going to be found in a different manner with regards to the way that it has been slanted.

Also, the maximum values of wind speeds have had a tendency to increase over time on the tower. The maximum wind values around the tower over time have gone up over time (Solari, et al 1998: 6). This is a sign that the wind that is being handled by the tower might be influencing the ways how the tower moves.

The wind conditions may not be as substantial to the Tower of Pisa as what some people might have them out to be. However, the ways how the wind can get onto the tower are important to see because of how they are all areas that are going to be impacted in a number of ways.

2. 4 A look at the foundation

A big consideration over how the Tower of Pisa has gotten to its current state comes from its foundation. The foundation used to help support the tower is very weak. A big part of this comes from how the foundation is not very great and is relatively weak.

The depth of the foundation is the first critical feature to see with the tower in mind. The tower is about 60m in height and 20m wide at its base. The foundation, meanwhile, is only 2m deep. The fact that the pressure on the building is about five kilograms for every square centimeter does not help (Terracina 1962: 336).

This can suggest that there was not enough soil used during the construction of the tower to help with supporting the build of the tower. A proper building will need to work with a stronger amount of a foundation to help with improving its ability to stay upright without any problems. The soil has changed so much over the years that it has fallen to where the tower¿½¿½s stability has been substantially compromised.

An interesting part of the foundation comes from how the sands in the area are relatively thin. The sands at the top part of the ground for the foundation are about ten meters deep. The layers of sand are relatively thin (Jamiolkowski 2001: 16). This has been interpreted by some people as a major reason as to why the tower has fallen so much and may end up influencing the ways how the tower can be fixed.

An important problem that is going to continue to influence the foundation comes from the aforementioned added pressure that is found at the southern part of the tower. A big factor comes from how the soil that was

prepared during the construction of the tower was easier to compress on the southern end of the tower.

However, over the years the soil has changed to where it is easier to compress on its northern end. This is a factor that will end up influencing the way how the tower is going to stay upright and its general ability to handle different pressures (Terracina 1962: 337).

It is even estimated that the pressure of the tower with regards to the foundation has increased over a period of time. This is due to how the tower has fallen to the point where the incline from the foundation has caused the tower to deal with a pressure that is higher now than it was about two or three centuries ago. This is a very worrisome consideration that has influenced the ways how the tower is slanting (Terracina 1962: 338).

In fact, the foundation itself has influenced the tower to where it is at an inclination of about ten percent. Reducing the inclination by at least one percent may be enough to help with improving the ability of the tower to be more comfortable (Terracina 1962: 338).

The best thing to see about the tower is that it is one that has dealt with soil that has been influenced over the years. The fact that the soil was impacted so much over the years, particularly from how there had been so many delays in the construction of the tower when it was first built, are both factors that may relate to what has caused the tower to fail as much as it has.

It is also good to take a look at the way how the soil is built in the area. This is related to details that were mentioned earlier on in this report.

Overall, the foundation is a real function that was difficult to use in the construction process. This is a worrisome concern but it will still be valuable to see with regards to how the tower was made.

2. 5 Other towers with similar problems

An interesting part of the Tower of Pisa is that while it is a unique tower it is not the only tower in the world that has had to deal with a similar concern with regards to its incline. A church tower in Nijland, which is a town located in the Netherlands, dealt with the same concern as that of the Tower of Pisa. The lessons that were involved with this tower are ones that may end up influencing the ability of the Tower of Pisa to be corrected in the future. It will help to take a look at the story of this tower to see what can be done in the future in order to possibly correct the tower.

It will help to take a look at the background of this building in order to see how its lessons can be applied. The church tower in Nijland was built in 1275 off of a sandbar. In 1600 the tower was updated to where a bell tower that is a little over fifty meters in height was built. This is an area that included a new bell that would be used on occasion (Barends 2002: 142). The tower that was constructed here is the main focus point to see in the process.

The tower had ended up tilting in its build in 1865. The tower was tilted in a southwestern direction. A year later an investigation on the tower revealed that the tilt involved with it was even more severe than it was the first time

around. The finding found that the tower was at risk of falling over primarily due to the risk associated with the increase in the tilt on the tower. This was an especially concerning function for people in Nijland to consider due to how the tower was built centuries earlier and had been a great part of the local pride of the town.

The fact that there was a large bell on the tower would end up making this harder to deal with. The bell would be responsible for adding a large amount of pressure that could have caused the tower to fall.

A big part of how the tower was fixed came from how the soil was adjusted underneath the tower. This was used as a means of helping to bore out soil. This is a process that involves creating a large hole under the soil.

One of the most unique features that came in the construction came from how the tower had to be separated from the rest of the church. This is different from what was handled with the Tower of Pisa. Whereas the Tower of Pisa is one that is completely independent from other structures, the tower in Nijland was built with a series of walls and supports around the area. This is needed as a means of helping to improve the ability of the tower to become corrected.

The fact that the tower was build separately from the rest of the building is a ready why this part of the process could have been supported. This is something that makes the tower different from the Tower of Pisa. The Tower of Pisa was built at one time and has never dealt with any additions outside of the items that have been implanted into the area over the years.

Soil from underneath the tower was reviewed and then prepared before it could be packaged into the tower area again. Soil was taken out in small parts and was wetted over a period of time in order to get it to have an easier time with mixing with the clay in the ground.

The tower was able to be placed back together after the process was completed. Since then the tower has not experienced any problems with regards to the way that it is built or any incline concerns. In fact, the tower has not dealt with any problems with its incline as a result of the ringing of the bell that it located on the very top of the tower (Barends 2002: 141).

It should also be noted that the foundation itself had to become partially detached just to get the procedure to work. However, it was fixed as soon as the repairs to the property were completed (Barends 2002: 142). This was used to ensure that the masonry on the tower would not be destroyed. However, the tower here is much younger than the Tower of Pisa was and therefore might have involved a form of masonry that could have been easier to handle.

This is a procedure that, like the Tower of Pisa procedure, has proven to be successful simply because of how it has worked to keep a tower from collapsing off of its foundation. The difference though is that the Tower of Pisa is still tilted on its side. The Nijland tower is fully upright and not at risk of being damaged in any way.

It is important to take a look at this feature when working to get the Tower of Pisa to be corrected. This may end up influencing the way how the tower is

going to be handled in the future. Learning from the past may be the best way to get the Tower of Pisa to be prepared and saved for the future.

3. Conclusion

The Tower of Pisa is a truly historic site that is very unique for the way how it has tilted. However, in order to preserve this building for future generations to enjoy, it will be important to take a look at the way how the building is going to be treated with regards to keeping the tower from collapsing.

It will be very critical for people to take a look at why this tower has fallen as much as it has and how it has been handled in the past. The way how the process was handled was very difficult and is a good reason as to why the building has fallen. The build of the soil in the area and its foundation is also notable.

It is also important to see how different factors can easily influence the way how the tower has tilted. This is critical because there is a potential that the tower can still be saved. Past tests have found that different buildings that have dealt with similar tilting concerns have been fixed in the past to where they will no longer be dangerous and likely to topple.

It will be important to look into all of these parts as found in this report. These are all parts that suggest that the build of the tower will need to be reviewed in order to ensure that it will have an easier time with staying upright for a longer period of time. This is so it will be safe in the future. The Tower of Pisa is a truly important building to the history of the city of Pisa and is one of the world¿½¿½s most notable marvels. The ability to get this

handled properly will be important to see when trying to get the building to be saved for future generations to marvel at and be interested in it.