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January 18, 2017

The Hagia Sophia

Part 1: Human Aspects

1.1: A Brief History

Three separate churches erected in Constantinople were all dedicated to the wisdom of Christ and erected on the same site one after the other. These churches were built between 360 and 537 AD by three different emperors: Constantius II, Theodosius the Younger, and Justinian I. The first two churches were consumed in flames after relatively short lives, but the final and greatest church still stands today, despite a history of extensive damage. This final edifice is the main focus of this paper, owing to its 1500 year longevity and unprecedented architecture. If the entire History of Justinian's church is to be considered, it is inaccurate to refer to it as a "church," because although it remained a church for the first 900 years after its audacious construction, it was later converted into a mosque. Today it is a museum, in remembrance of its long history. (24).

Constantius II is credited with building the first Church of Christ's Wisdom in Constantinople, but the idea was that of his predecessor, Constantine the Great.

It was Constantine who founded Constantinople as the capital of a new, Christian empire. Rome had grown from pagan roots since its founding and wouldn't suffice as the capital of a Christian empire.

Constantinople was also built on a very strategic site. Situated on the Bosphorus it is both highly accessible for trade, and easily defensible in war, as the Ottomans and Latins would later discover. He had for a while been incubating the idea of building a great church in his new Capital city, perhaps as a counterpart to the famous Church of Saint Peter in the former capital of Rome. Since Christianity was no longer ostracized after Constantine issued the Edict of Milan, more churches were needed for the public accommodation of the hitherto secretive Christians. Although he did not see this accomplished in his lifetime, it is said that he gave a direct command to Constantius II, his son, to build this church.

It is not known exactly when construction began, but as it rose from its foundations, it was referred to simply as "The Great Church." This continued to be an epithet for even its successors on the site that would only later come to be referred to as Hagia Sophia. It was completed round 350 AD and dedicated by the Bishop Eudoxius ten years later as "The Immortal Wisdom of Christ (22)."

But unlike the wisdom of Christ, the church was short lived; it burned to the ground in June of 404 AD after being set afire by a riotous mob. (24). The rioters were grieved over the second-time exile of their beloved bishop, John Chrysostom. He was outspoken in his tirades against the power structure, especially the Empress Euphemia. (22).

Although it was short lived, something should be said about the structure of the first Church of The Immortal Wisdom of Christ. The church was rectangular. It was divided longitudinally five times

North to South into aisles around the nave by rows of pillars parallel to the longer sides. It was divided East to West by the Narthex, or vestibule, the nave, or main church area (12), and the sanctuary apse, containing the altar. Its roof was primarily made with wood, except for the semi-dome above the sanctuary apse. An atrium demarcated by colonnades preceded the narthex. (24).

The reconstruction was undertaken and completed in a short time under Theodosius the Younger. The new church was rededicated as Hagia Sophia, or Holy Wisdom (of Christ). It was constructed on the same plan as the first, and proved no less susceptible to fire. (24). Only 117 years later, it was consumed thereby during the course of the infamous Nika riots when the Blues and Greens, opposing factions in the hippodrome, united against Justinian and forced him to release some prisoners of both factions. But even when their demands were met they continued to riot. Empress Theodora convinced Emperor Justinian to remain in Constantinople against his intentions to flee. Instead, he remained in power by releasing armed forces into the 30,000 enraged citizens. The army drove the rioters into the Hippodrome and slaughtered till none remained standing.

Now it fell upon Justinian to continue the legacy of Hagia Sophia. The evidence shows that he had been contemplating the replacement of the Theodosian edifice for years prior to the Nika riots. This seems highly probable since he began construction on his church on February 23, 532 AD, only thirty nine days after the destruction of the previous Hagia Sophia. When the unprecedented scale and design of Justinian's Hagia Sophia is considered, it seems impossible that any architect could have planned out the entire project in just over a month. Justinian must have confided in Anthemius of Tralles, one his chief architects, his plans to build a new and entirely astonishing church long before the Nika riots. This gave Anthemius the months or years required to study the project. (16).

This unprecedented church was erected in an unprecedented time period as well; it was

completed on December 27, 537 AD, just five years and ten months after construction began.

Anthemius of Tralles and Isidorus of Miletus were the chief architects. But, just twenty years later the first dome collapsed. Isidorus the Younger, the nephew of Isidorus of Miletus, built the second dome. At that time Anthemius of Tralles was dead. Parts of this dome have survived 1500 years to the present day. (16).

Procopius, a historian contemporary with Justinian, recounts that 10,000 workers were employed building the Hagia Sophia not including the many artists and experts. These employees all drew salaries. When that expense is added to the cost of the expensive building materials such as marble, silver, gold, jasper, and porphyry, the cost must have been incredible. Around 1940 AD, estimates of its cost exceeded 75 million dollars. Taking inflation into account, an equivalent amount in 2018 AD would be worth approximately 1 billion dollars (36). This seems extravagant but Justinian had a reputation from his numerous and expensive building projects for long before he built Hagia Sophia. It is for this reason that he taxed his people so heavily; to fund his innumerable projects. In light of this aspect of Justinian's character, it is perhaps not surprising that he chose to undertake such a large and expensive building project. (24).

Other than as a display of his immense wealth and power, what were Justinian's motives behind building this grand structure? The simplest explanation is that Justinian's empire had a need for more churches. Not necessarily the need to accommodate a larger Christian population, but to reassert Orthodoxy. The number of clergy members had been restricted, so there was little practical requirement for new churches, especially such large and costly ones as Hagia Sophia. But there was a growing schism between Orthodoxy and Monophysitism. Justinian may have envisioned a rebirth of Orthodoxy as the dominant religion as a result of his splendid new church. However, those hopes were never fulfilled. (22).

The Hagia Sophia remained a church for 916 years, but it was not always an Orthodox Christian church. From 1204 AD to 1261 AD it was the house of Roman Catholicism. This came about in a series of astonishing events that would be described as brought about by the “hand of God,” at least by the Roman Catholics. (24).

It began when When Pope Innocent III (1198-1216 AD) called for recruits to wage the Fourth Crusade. The only stock of fighting men available came from Flanders, Champagne, Blois, Monteferrat, and St. Pol, all provinces of Western Europe. At the core of the army were noblemen from these provinces; Count Hugh of St Pol, Count Louis of Blois, Count Baldwin of Flanders, his brother-in-law Count Thibaut of Champagne, and Marquis Boniface of Montferrat. Many of these men had participated in the Third Crusade (1189-1192 AD) and they were all aficionados of the popular tournaments of the day. These involved large numbers of men over many acres and were designed to provide a very close approximation of real war. So these leaders were men highly experienced in war and fighting. (23).

In April of 1201 they went to the acknowledged maritime masters of the day, the Venetians. They requested passage to the Holy Land and provisions for 33,500 men for a year, in exchange for 85,000 silver marks. An equal force of Venetians were to accompany the crusaders. These were to be lead by the doge, chief magistrate, of Venice, Enrico Dandolo. He was a blind, ninety year old man, but was to prove invaluable later on. (23).

But by Summer of 1202 AD, only ten thousand men had landed in Venice, and were unable to pay the price. Dandolo then suggested that the crusaders sack the nearby port of Zara for supplies and ships. Zara, however was a good Catholic city and many men refused and went home. But there was

still a significant number of men convinced that this action was necessary for the completion of the crusade, which in their minds was God's will. They were even willing to bear certain excommunication that would come of assaulting their fellow Christians.

Pope Innocent immediately excommunicated them after they took the port on November 24, 1202. But the Pope was later convinced, as were the crusaders, that the action was necessary for the recapture of the Holy Land as Dandolo counseled, and rescinded the excommunication from all but the Venetians, because they did not apologize. (23).

But the crusaders still lacked the necessary supplies and men to set sail. When an envoy from the Byzantine Prince and claimant of the throne Alexius Angelos arrived in Zara, they were well aware of this. Alexius offered 200,000 silver marks, as many supplies as the crusaders required, and an additional 10,000 troops to accompany them on the Crusade if they would help reinstate him as emperor of Byzantium. Again, many of them refused to take up arms against Christians and left. And again the remnant saw that such sacrifices were necessary; Alexius' offer was the only means by which they would reach the Holy Land. (23).

Thus, their course was diverted to Constantinople where Alexius had promised that he would be welcomed. However, upon crusaders' arrival at Constantinople in June of 1203, it became apparent that the Prince was unpopular; force would be required. The crusader army shuddered as they gazed at the mighty Theodosian walls. But little did they know of the internal weakness behind this impressive facade; For years prior, feuds, insurrections, and rebellions had racked the Byzantines. They had been diminished further by external assaults and seizures of their territory. Their decline in military prowess is then no surprise. Their naval fleet was comprised of "twenty half-rotten ships" by the time of the fourth crusade. And the Crusaders commanded the finest ships and sailors of the day. (23).

Constantinople was a populous city so the Byzantines had the advantage of numbers. But the Byzantines lacked steadfast leadership; the current Emperor Alexius III would prove a coward; He assembled a massive army outside the city in response to Dandolo's onslaught, but when the two armies confronted each other, Alexius led his men back inside the walls to the utter surprise of the Crusaders, who saw it as a sign of resignation to defeat. The Byzantines were also shocked and Alexius III was exiled. Then Prince Alexius Angelos became Emperor Alexius IV and it seemed as if the Crusaders would finally be on their way to the Holy Land. But when the new emperor pressured the Byzantines for the money he owed the crusaders, he fell out of favor. He was murdered ten months later by the anti-Western noble Murtzuphlus. By April of 1204 AD, the crusaders were struggling to find supplies outside the hostile city. (23).

In desperation, they launched a final attack on April 9, 1204 AD. This time, the Byzantines were ready: they had prepared additional wooden fortifications atop the wall to prevent the Venetian siege towers from scaling the walls and doubled the size of their army. As the battle unfolded, it seemed that the Byzantines would prevail, when the winds changed; The crusader vessels could now access a vulnerable seaside wall section. On the ground, a breach in the wall was discovered and soon the city had miraculously fallen to the Crusaders. The barbarians had defeated the Christians, or so it seemed to the rest of Byzantium. But the Latins were in fact Christians themselves, if only a remnant willing to turn against their fellows. Nonetheless, little was to be seen of religious principle as the literal and figurative rape of Constantinople ensued. The wealth of the churches including Hagia Sophia was pillaged. All of the gold and silver decor and priceless relics were stolen. Count Baldwin of Flanders was crowned Emperor Baldwin I over the new Latin Empire inside the violated Hagia Sophia. When Pope Innocent III heard of his victory, he was at first overjoyed. But he slowly caught wind of the Crusaders' atrocities and then denounced their actions. (23).

As if by divine punishment, the crusaders' victory was short lived. They found themselves thousands of miles from home and surrounded by hostile Byzantines. Fifty seven years later in 1261 AD the Byzantines had recaptured their capital city of Constantinople. They found Hagia Sophia in a dilapidated state with a ruined, dull interior. (23). By this time, the Byzantines were no longer wealthy enough to replace all of the lavish ornaments that had been possible in Justinian's reign. But they repaired it as they were able. In 1317 AD engineers warned Emperor Andronicus Paeleologus the Elder that collapse of the Northeastern vaults was imminent. He quickly arranged for huge, external buttresses to be erected to stabilize Hagia Sophia. These are very prominent features today not only because of their size, but because of the difference in architecture between them and the original edifice; They show a remarkable deterioration in architectural taste and workmanship. (24). And just twenty seven years later the buttresses proved useless when in 1344 AD another earthquake cracked the dome. (22).

That was the last repair that the Byzantines made on Hagia Sophia because it was soon to be out of their possession. Constantinople fell to the Ottoman army of Sultan Mehmed II on May 29, 1453 AD. The battle unfolded over 51 days from April 6, 1453 AD to May 29, 1453 AD, but Mehmed had begun preparations for the battle a year earlier. He constructed massive cannons in Hungary, assembled an enormous sixteen galley fleet, built Rumelli castle on the European side of the Bosphorous to control that area, and formed a pact with the nearby Genoese to keep the province of Galata neutral during the the battle. In the beginning, the battle went badly for Mehmed; The Byzantines had defeated his fleet and successfully received three ships loaded with weapons and food from the Pope. Morale was falling and Mehmed's troops were abandoning the cause. The Byzantines offered peace but Mehmed refused; he had been inspired by a letter from his spiritual teacher to continue the conquest. He launched a surprise attack while his cannons continued to crumble the great walls of Byzantium. He

transported a fleet of ships overland into a bay that the Byzantines thought well fortified. They panicked at the sight of Mehmed's fleet somehow inside their fortifications. The tides of the war had turned against Byzantium and in the next weeks the Ottoman army emerged from the fray victorious. (25).

The Ottomans immediately converted the Hagia Sophia into a mosque with a formal rededication. They removed all portable christian icons, but did not paint over all of the mosaics. They removed all of the Christian liturgical furnishings and installed their Muslim counterparts. They hung the world's largest, wooden calligraphy panels and carried out renovations at various times (1). They kept its name but changed the spelling to Aya Sofya. Fatih Sultan Mehmed II the Conquerer had a temporary wooden minaret built at the Hagia Sophia while the Ottomans built each at different times four more minarets of less perishable material around the main church. A minaret is tower with small windows and an opening on the top (33). They are located at or near mosques for ritual purposes. As a final touch, they lavished the interior with carpeting. (22).

But the newly established Ottoman Empire did not enjoy the extreme longevity of the Byzantine Empire; it persisted a little over 500 years vs. the 1500 year span of Byzantine rule. It fell in World War I. At that time, the erratic Mustafa Kemal Atatürk made the unexpected decision in 1935 to convert what was the greatest mosque in the Ottoman Empire for a couple hundred years, Aya Sofya, into a secular museum. It has a very incomplete collection because of the periodic destruction and removal of artifacts as described above, but remains a popular museum to the present day. (34).

1.2: Liturgy and Ritual.

The Hagia Sophia has been occupied by three different religions in its history; Orthodox Christianity (the Byzantines), Catholicism (the Latins), and Islam (the Ottomans). That means that three different liturgies were conducted inside the holy building.

The first liturgy was that of the Orthodox Byzantines. This was comprised of three main rituals; the singing of the Divine office, the Eucharist, and the baptismal rite. All of these rituals require certain liturgical furnishings. These included an ambo, altar, chancel screen, synthronon (1), ciborium, and solea (22).

The ambo was a feature of early Christian churches such as the Hagia Sophia. An ambo is a raised pulpit with two staircases from which the reading or chanting of epistles and gospels is done and sermons are conducted, in front of the altar (7). An altar is structure that is usually raised, upon which ritual incense burning or sacrifice is conducted during worship and where the gifts of the faithful are placed and consecrated (9). A synthronon is a “half-circular staircase” (1) where the clergy and bishop (or choir (10)) sit; it is placed behind the altar (8). On the top of the synthronon was placed a throne for the emperor, bishop, patriarch, or the most important person attending service on a given day, the prime celebrant. This area of synthronon, throne, and altar is called the chancel (11). It is separated from the main church area, or nave (12), by an ornate screen called the chancel screen (10). The ciborium is a canopy above the altar supported by four pillars around the altar (26). The solea is a raised platform in the inner sanctuary upon which the faithful receive communion and the choir stands (27). The liturgy involved all of these furnishings.

The singing of the Divine office was held either on the synthronon or the solea. This is where the choir was arranged. The arrangement of lighting inside the chancel and the nave was centered

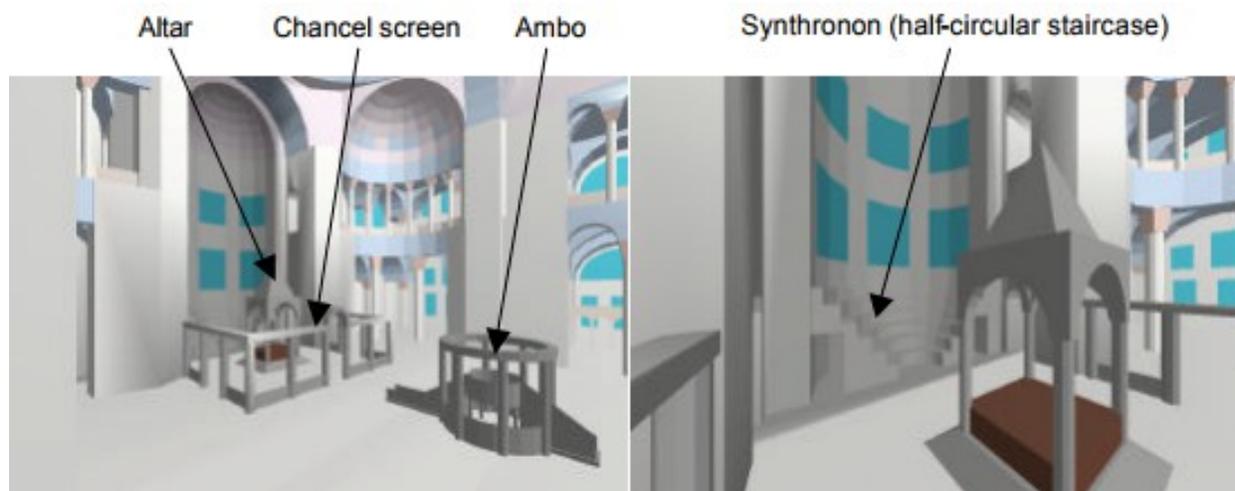
around this ritual.

But the Eucharistic service had greater architectural demands. Before the service, a formal entry was conducted, led by the prime celebrant. On important occasions, the patriarch would lead the procession with a deacon bearing the gospel following along with the remaining clergy. A prayer would be given at the central door to the narthex. This Eucharistic liturgy involved common people, a bishop, the lower clergy, and catechumenes. These groups were separated inside the church based on their roles in the service. The men of the congregation would stand in the nave around the ambo, while the women occupied the galleries to the side. The Bishop would occupy the ambo and also the throne, if the emperor or patriarch weren't present. The lower clergy would line the steps of the synthronon. The prime celebrant would occupy the throne. The prime celebrant would lead the clergy down the center of the nave to the chancel. Once everyone was properly situated, he would address the congregation. The actual service usually began with a sermon delivered from the ambo by the bishop. Next, prayers would be taken. Then, as a sign of peace, there would be a kiss of Peace. Finally, all present would hold communion before dismissal. The catechumenes, students of the faith not yet accepted as full members (28), would attend the service but would be dismissed before the communal prayer. (22).

The baptismal rite had little to do with the Hagia Sophia church itself; it was conducted in either of two baptisteries outside the church. (22).

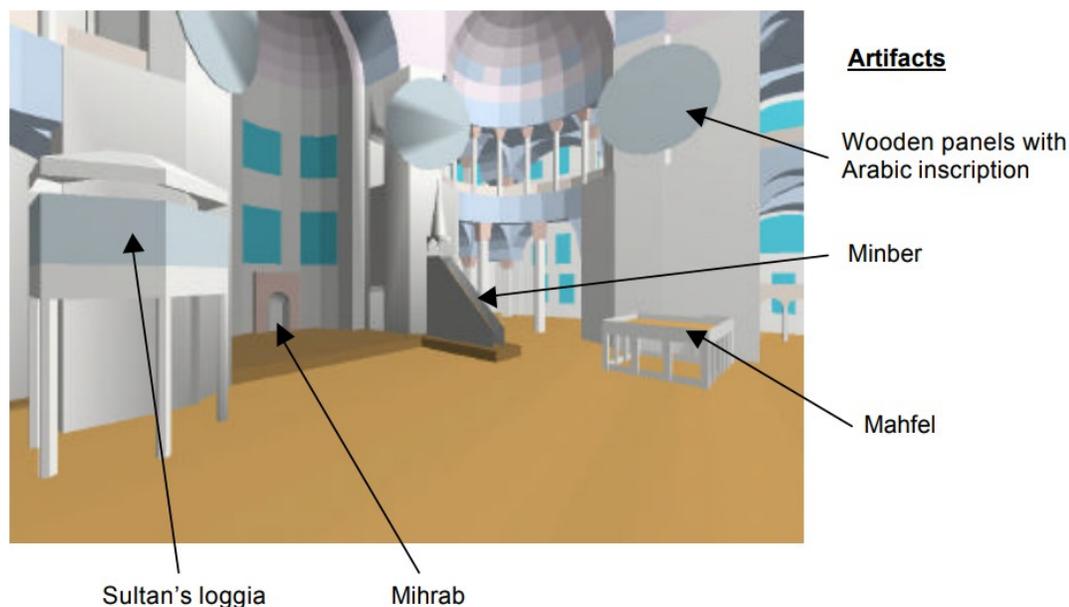
There is seemingly limited knowledge about the Liturgical rituals of the Roman Catholic Latins during their 57 year occupancy of Constantinople and Hagia Sophia. However, they celebrated the Eucharist just like the Orthodox Byzantines, with minor differences such as using unleavened bread instead of leavened bread. Of course, their rituals involved the pope instead of a patriarch. Furthermore

it isn't known how much Hagia Sophia was in service during the Latin Occupancy; they stripped all of the silver sheathings and valuable gold artistry, even the marbles were disturbed (22). This seems to suggest that they didn't have much care for Hagia Sophia and after their ransack of the Church, it surely did less to inspire divine ambitions. (29).



After the 1453 AD fall of Constantinople, Orthodoxy lived on under the tolerant rule of Mehmed II, even though most of the people became Muslims and most churches, including Hagia Sophia, were converted to mosques. When the Ottomans converted Hagia Sophia into a mosque, they removed all of the Christian liturgical furnishings and replaced them with several pieces of comparable furniture to complete the conversion of the Holy Wisdom into a mosque. Among these additions were a Sultan's loggia, a mihrab, a mahfel, and a minber (1). The Sultan's loggia was a large balcony with arched windows to the open air, for the Sultan's enjoyment (2). The mihrab is feature common to all mosques. It is a structure built at the point inside the mosque that is closest to Mecca, towards which a congregation turns to pray. (4). In the Aya Sofya, it was shaped like an arched doorway (1). The minber, or minbar, is a short flight of steps that a Muslim preacher, or imam (5), ascends to address his congregation (3). The mahfel (1), or *muezzin mahfili*, is an elevated table or dais that the muezzin will mount and repeat the words of the imam. This feature is only necessary inside large mosques where at least part of the congregation is likely to be too far away to hear the imam. (6). Prayer services began

five times a day, when a muezzin carried out his duty to call the men to prayer from the opening at the top of the minaret. (13). In Mosques, the Islamic equivalent of the sermon is conducted by the Muslim religious teacher, or imam to a congregation with the help of the muezzin atop the muezzin mahfili. Only men are allowed to hear the religious teachings inside the mosque.

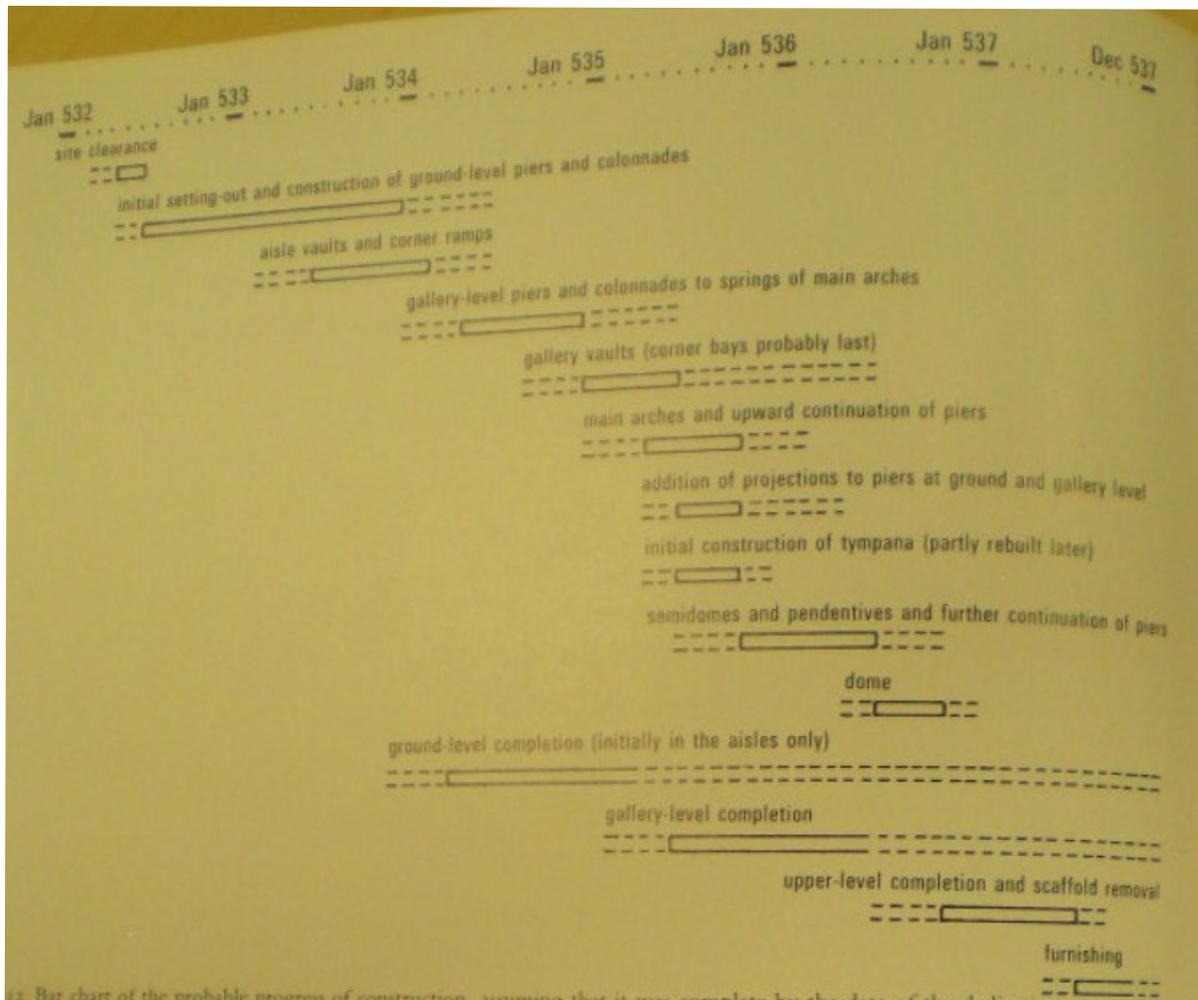


1.3: Acoustics

As an interesting side note, we will consider the acoustical aspects and overall impact of the different liturgies. The main differences are between the Orthodox liturgy and the Ottoman liturgy due to the major changes that the Ottomans made inside the church; namely the hanging of massive wooden calligraphy panels and carpeting the floors. The carpet in the mosque prevented sounds from reverberating as long as they did in the church. The church reverberated sounds for as much as eight seconds do to the hard and rigid surfaces. This would have created overlays; as one sound died out another would have begun; maybe this made the liturgy slightly harder to make out. Inside the carpeted mosque, sounds were slightly louder inside of the mosque than in the church or museum, but reverberated less do the carpeting's damping effect. Even with these effects, a muezzin mahfili was still required for such a large mosque (1).

The Byzantines between 537 AD, when the church was first dedicated, and 557 AD, the time of the collapse of the first dome, were witness to Hagia Sophia at its most glorious; with all of the gold and silver and mosaics intact. The effect of stepping into the nave from the narthex must have been truly awe inspiring. The dazzling ceiling vaulted to sky heights and the dome appeared to float above in the firmament. Historians of the day often described it as Heaven on Earth. But as we have seen, Hagia Sophia suffered much in the 900 years up to the Arabic conquest, and while the religious affect of Hagia Sophia is still strong today, it is was much diminished. Even in its dilapidated state, Hagia Sophia still remained the most important mosque in the Ottoman empire for a couple of centuries. As we have seen, mosques after the Ottomans witnessed the grand Hagia Sophia were generally larger with more luxuriant decoration, and almost always unified under a central dome. (22).

1.4: Construction



22 Bar chart of the probable progress of construction, assuming that it was complete by the date of the dedication.

Figure 2: A bar chart that shows the timeline of construction, assuming that it was finished by the time of dedication. (22).

Construction began on February 23, 532. Justinian employed 10,000 workmen and 100 foremen to build Hagia Sophia. This vast workforce was able to complete the project in just under six years. There is no comparable building that has been constructed in under thirty years! The following is a tentative guess as to how the construction would have progressed. (22).

The first step was to clear the building site of any trees, large stone, or other obstacles. This took approximately four months. After the site was leveled, work began on the foundations and setting up of the ground level colonnades and piers. This work stretched from April of 532 AD to June of 534 AD. After the first half of this job was completed, work began on the vaults of the aisles and the ramps at the corners. These were also completed in June of 534 AD. In December of 533 AD, the workmen began building at the gallery level. There, they completed the piers and colonnades as well as the springs of the arches, all by May of 535. In July of 534 AD, construction of the gallery vaults and corner bays began, and was completed by June of 536 AD. The main arches were constructed from between November of 534 and December of 535. During this time the piers also had to be made taller. Work on both the projections from the piers at ground and gallery level and initial construction of tympana began in February of 535. The latter were completed by August of 535 AD, the former by February of 536 AD. By March of 535, the upper level had been reached. And by August of 536 AD the semi-domes and pendentives were built with an upward continuation of the piers. Then the structure was crowned with a dome that was built in the period from January of 536 AD to December of 536

AD, less than a year. The ground level and gallery level must have both been completed by December of 537 AD. The scaffolding on the upper level was removed by July of 537 AD. Finally, furnishings were installed from August of 537 AD to December of the same year. (22).

To complete such a vast structure in such a short period of time, Justinian's builders needed quick access to construction materials. It is no surprise, then, that the 104 pillars needed for upper and lower colonnades were pirated from preexisting structures. As Justinian urged his builders to work as quickly as possible, they had no time to wait for new columns to be carved. Justinian ordered that all of the best materials be gathered from around the empire to build his grand church. In addition to the columns, he appropriated the marbles and other expensive materials from various ancient cities; the white marbles were gathered from Marmara island in the sea of Marmara that laps the shores of Constantinople, the pink marbles came from Afyon in Western Turkey, the yellow from North Africa, and the green porphyry from a Greek island called Egriboz. (34).

1.5: Architectural influence

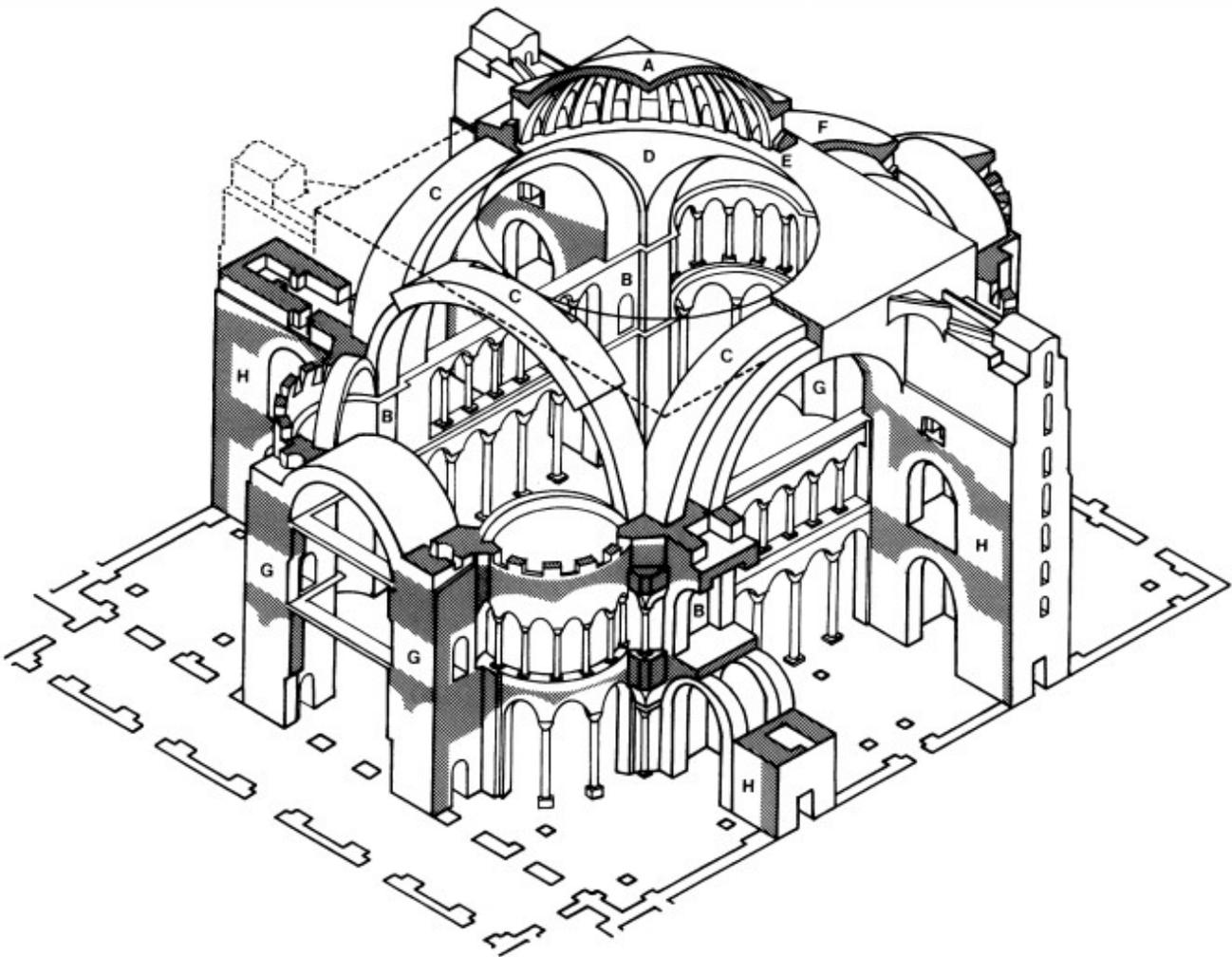
The architects of the Hagia Sophia invented the idea of using only four piers to support a central dome, instead of the traditional six, and using pendentives to join the supporting arches of the dome above the piers. This gave future architects more flexibility. After the Hagia Sophia, the centralized dome became the only appropriate plan for later orthodox Christian buildings. When Mehmet the Conqueror claimed Hagia Sophia as a mosque, they observed the superb structural unity under a centralized dome. After that, all mosques began to be planned in a similar way. But before the Muslims were witness to Hagia Sophia, their mosques were comprised of square rooms often arranged in a T shape. (22). The main inheritor of Byzantine architecture and culture was Russia, where Orthodoxy is at its strongest today.

Part 2: Material Aspects

Figure 3: Cutaway view of the Hagia Sophia main structure highlighting important structural features.

2.1: The Original Structure

We have now discussed the many aspects of Hagia Sophia associated with people and now it is



time to examine the material aspects of the structure; The top of the dome (A) today is 184 feet above the ground and 102 feet in diameter. (30). It has a height of 48 feet from the upper cornice, slightly shorter than a perfect hemisphere would be. The main piers are 74.17 feet tall. (16). The floor under the dome is 100 feet square, the corners demarcated by the four main piers. (16). It rests directly upon the prominent, horizontally projecting feature that surmounts the walls (21), or the cornice (C). The

Cornice projects a few feet horizontally into the nave at the base of the dome. This area is utilized today as an inner walkway around the base of the dome. The curved, triangular surface (D) is the intersection between the dome and two arches; the pendentive (20). There are four, one at each corner. The dome rests on flat, marble blocks (E) that are arranged to form a slightly deformed circular space concentric with the dome (see figure 4). The four main arches spring from four massive piers (B) situated at the corners of the of the main, square structure. The half-domes (F) are partly supported by the main piers and partly supported by four secondary piers (G), two at each end of the nave. External buttresses (H) serve to resist the outward thrust of the main dome. (16).



Figure 1: A view of the central dome of Hagia Sophia from below. Note the small irregularity of the upper cornice. Note that the foundation of the dome springs directly from the upper cornice. Source: <https://www.flickr.com/photos/ficablok38/8432896767>

The first dome of the Hagia Sophia was completed in 537 AD by Justinian's master architect appointees Anthemius of Tralles and Isidorus of Miletus. It collapsed twenty years later, after it lost the support of the Eastern main arch, which had crumbled due to an earthquake. When a second dome was constructed, a sixth century historian called Agathius, who probably observed both the first and second domes, remarked that the second dome was less amazing than the first. The second dome is widely famed today as a great architectural feat. How was the first dome more awe inspiring? We must look

for structural and literary evidence to learn about the original structure and the first dome.

One theory as to why the first dome was more incredible, is that the first dome was flatter, without windows, and rested upon a cylindrical structure of the same diameter, or drum (31), that was fenestrated (32), or pierced with windows. The flatness of the first dome made it a greater architectural feat, but less stable. This contributed to the first dome's sudden demise. (16).

Not only did the flattened first dome exert more force on the weak ribs around the crown than on the stronger main arches, but these main arches themselves and the main piers suffered structurally from spreading. Before the mortar set, the weight of the building slowly distorted the structure into a rectangle instead of the square defined by the main piers. The north-south dimensions were the most unstable, and elongated. (16).

Agathius' statement that the second dome did not “strike viewers with as much amazement” as the first dome did, is understandable when one considers Procopius' account of the main dome. He compares the Church of the Holy Apostles' domes, five in all, to the main dome of the Hagia Sophia. All of the domes of the Church of the Holy Apostles were set upon drums, the central one “Divided by windows.” If viewed from inside the nave, the fenestrated drum would have been obscured by the cornice, creating a visual effect that the dome were levitating. Such is Procopius' description. This would strike the viewer with more amazement than a dome such as the second one that rises directly from the cornice, its foundations being visible from below (see figure 4). (16).

2.2: Materials.

The church had a smooth, marble floor. The main structure was constructed with stone. Plaster and paint were applied on some areas of the ceiling. Many different materials including gold, jewels, colorful stones, stained glass, etc were used to create the mosaics. Glass was used for windows. A silk cloth was present at the altar(1). The mosque contained wood for the sign discs, and carpeting (1). The main piers were constructed with limestone and greenstone ashlar. Ashlars are rectilinear stone blocks cut to the same dimensions in order to allow the use of very thin mortar joints (17). Some of these were hewn of greenstone, a dark green, metamorphic rock containing minerals such as chlorite, epidote, etc.(18). The main dome is made of bricks cemented together with pozzolanic mortar. The pozzolan was crushed brick dust that gave much of the mortar joints a pinkish tinge. Some metal and tiny amounts of wood were used as structural ties. (22).

2.3: Earthquakes and Repairs.

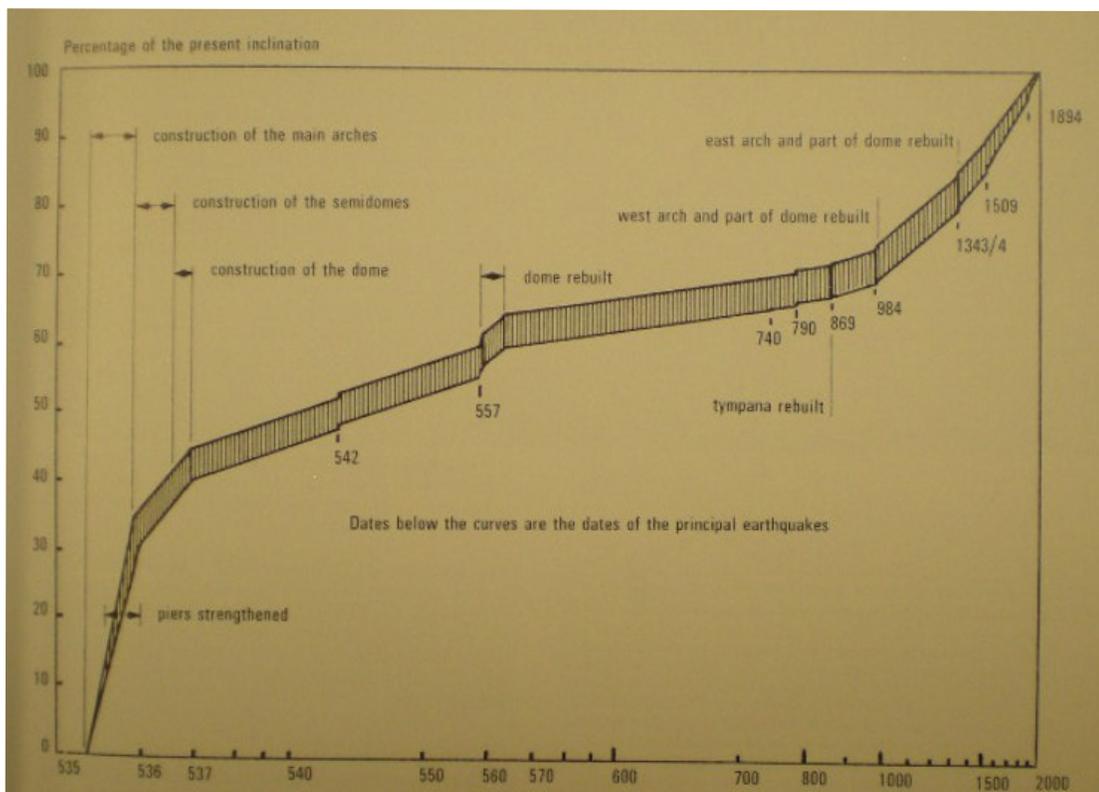


Figure 1: y-axis plots percentage of present deformation. X-axis is logarithmic time. Dates underneath bar represent significant earthquakes. Thickness of bar represents certainty of deformation percentage.

With the cautionary hindsight of the demise of Hagia Sophia's previous incarnations, Justinian built with no wood, except for a few timber ties (22). Thus it was not fire that threatened this building, but earthquakes. The speedy erection had grave structural consequences; the mortar did not have enough time to set completely before it was fully loaded. The result was considerable spreading of the piers and distortion of the arches. Thus weakened, the church could not withstand the several earthquakes that followed its hasty erection.

The first notable earthquake to occur after the construction of Hagia Sophia rumbled in 542 AD. It didn't do any significant damage. But another earthquake just fifteen years later destroyed one half of the central dome. The damage was so extensive, that Isidorus the Younger demolished the entire dome and rebuilt another dome from scratch. He was alone because by this time Anthemius was dead. The new dome was taller and its sides were more nearly vertical. This set up a much stronger geometry. Also, this new dome was sprung directly from the upper cornice; the first dome may have rested on a fenestrated drum. Two more earthquakes passed without harm, one in 740 AD and then another in 790 AD. The next earthquake came in 869 AD and destroyed the tympana. These were subsequently rebuilt. After a calm century, another earthquake struck in 984 collapsing the entire west arch and part of the dome. Following another long period of quiescence, another earthquake tested the structure again in 1343/4 AD. This time, it was the east arch proved weak and crumbled to the ground along with another section of the dome. The repairs were made quickly. The final earthquake to date occurred five centuries later in 1894 without causing considerable damages. The precise strength of the structure is not known; samples of mortar from the surface of joints have been analyzed, but the state of the

internal mortar is not known. (22). But, based on the loading analyses, T. Aoki *et. al.* Concluded that the structural weaknesses of the Hagia Sophia are greatest at the East and West arches and their two, adjacent half-domes. This is concurrent with the records of the Hagia Sophia's main dome collapse in the past and with what is known about the collapses of the east and west arches in 1343/4 AD and 984 AD, respectively (14). In the nineteenth century, the Swedish Fossati brothers extensively renovated the interior of the church. This included the removal of whitewash from certain mosaics. They also embedded chains at the base of the dome to contain the enormous outward thrust of the dome that contributed to its past instability. (22).

Neither are the precise structural properties of the minarets known, but a theoretical analyses has been conducted. It is useful to know the structural properties of the minarets because it allows scientists to analyze how they would perform in a earthquake today. First, the natural frequency was determined. The minarets have a natural vibration of 1 hertz, approximately. One minaret is constructed of bricks while the other three are built of stone. With this information, approximate values for the strength of the minarets could be determined. The Young's moduli, or the forces required per unit cross sectional area of a material to lengthen the material, simultaneously decreasing its width (15),, of the brick and stone minaret(s) are $2.8 \times 10^4 \text{ kg/cm}^2$ and $6.8 \times 10^4 \text{ kg/cm}^2$, respectively. The stone minarets are three times stiffer than the brick minaret. The brick minaret and the stone minaret are one seventh and one third the stiffness of concrete, respectively.

2.4: The Minarets

The first minaret erected at Hagia Sophia was a wooden one. This served until a brick minaret was constructed during the time of Fatih Sultan Mehmed or his successor Beyazid II at the Southeast corner of the mosque. The next three minarets were all built by the architect Sinan; the one at the Northeast side built during the period of Selim II and the other two built during the time of Murat III.

They are all about 197 feet tall. They were repaired during the sixteenth, seventeenth, and nineteenth centuries with the addition of ornaments. (35).

Minarets have an interesting history. The minaret at the Great Mosque in Kairouan, North Africa, is the oldest intact minaret, built in the 700s AD . It is possible that minarets modeled from Buddhist pagodas, the earliest of which were built of wood in 200 AD but later came to be built of stone, like minarets, around 500 AD. (13). “Minaret” comes from the Arabic word for lighthouse (33).

This single structure has reflected and absorbed pivotal moments in human history; its architecture has brought together historians and archaeologists over the centuries to discover the wonders of Hagia Sophia. Any building of such importance and impressive life span was have a lot to tell us about history; The great events orbiting around it; The great historians focused upon it; The great leaders vying to adorn their empires with such a jewel; Justinian's great Church: The Hagia Sophia.

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