Em Hotep Egypt for the Curious Layperson and the Budding Scholar

Hemienu to Houdin: Phase One, Part A—One Third of a Ramp, Two Thirds of a Pyramid

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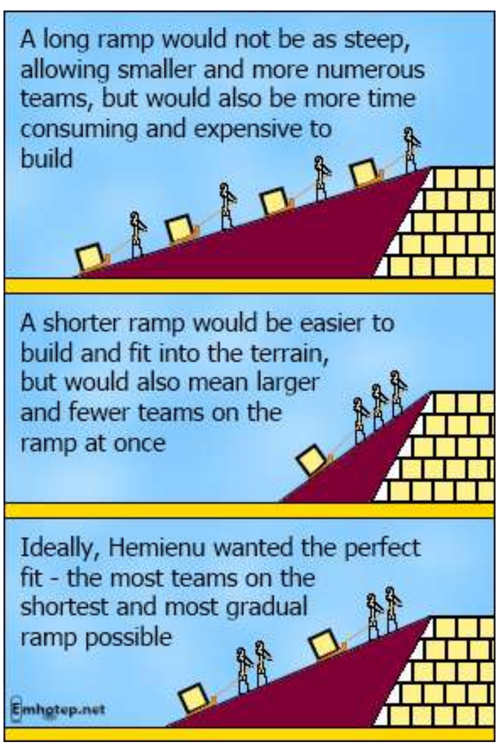
Intro

To understand how the Great Pyramid was constructed, and how Jean-Pierre Houdin's theory suggests Hemienu went about this work, it helps to outline the project in terms of three general phases. In each phase Hemienu had specific goals and confronted unique challenges that required individualized strategies. Each of these phases were literally built one on top of the other, so there was no room for Hemienu to make up the plan as he went along. Before even the first cut of the foundation was made he already knew how the pyramidion would be placed on the top.

Whether we are talking about the theories of Jean-Pierre Houdin or not, the pyramid was by necessity constructed in three phases: One—the bottom third, which contains all known internal structures except the King's Chamber; Two—the King's Chamber, during which the fiftieth level of the pyramid's blocks literally became the construction site of a monument built inside the monument; and Three—the completion of the top of pyramid.

In this current article we will examine how Jean-Pierre's theory describes the external ramp that was used to build the bottom third of the Great Pyramid. In particular we will see how Hemienu could have built two thirds of the pyramid with a ramp that only reached one third of its final height; we will see how the Great Builder overcame the limits imposed by the terrain and turned many of them to his advantage; and we will begin looking at how this deceptively simple structure solved some rather complex issues confronting Khufu's Master Architect.



Review of the Cons and Pros of a Straight Ramp

Nearly all theories of how the Great Pyramid was built involve ramps, with many of them describing a straight ramp leading up from the desert to the face of the pyramid. But as we saw in ***Part One: How Do You Prefer Your Ramp?***, there are many problems with this idea. One problem was how to keep the ramp from being too steep.

Most of the blocks used to build the pyramid weighed an average of two tons, and to keep the supply train moving fast enough to complete the project on time there had to be enough room on the ramp for multiple teams. In order to keep these teams small enough—about ten to twelve men was ideal—the incline of the ramp needed to be kept at a maximum grade of around 8—8.5 percent. The steeper the ramp is, the more men you need pulling the blocks, and the larger the teams are, the fewer you can have on the ramp at one time. The fewer teams, the slower the progress.

This presents a problem because the pyramid's original height was about 146 vertical meters. In order for a straight ramp to reach this high, while maintaining a grade between 8 – 8.5 percent, it would have to be over a mile long. So what is wrong with that? Couldn't the Egyptians, famous for their architectural feats, have built such a ramp? Sure, but not without extreme—and unnecessary—difficulty.

First, consider the terrain. The only place to build such a ramp would have been to the south. The plateau ends in a sudden drop just to the north, and there were cemeteries to the east and west that were growing even as the pyramid was being built. But a ramp that would extend over a mile to the south would not only cut through the main quarry, it would also run straight into the wadi, a gradual drop-off formed by a sort of canyon that defines the southeastern contour of the plateau.

Building into the wadi would have increased the size of the ramp much more than you might think. As the ramp spanned the drop-off formed by the wadi, the top—the walking surface—would need to maintain the same grade of around 8—8.5 percent, so the base of the ramp would need to be extended downward while the top remained at the same angle of descent. In order to maintain the structural integrity of the ramp, the base had to be wider than the top, with the sides leaning inward and tapering up to the walking surface. Otherwise it would grow top-heavy as it became too tall, and collapse.

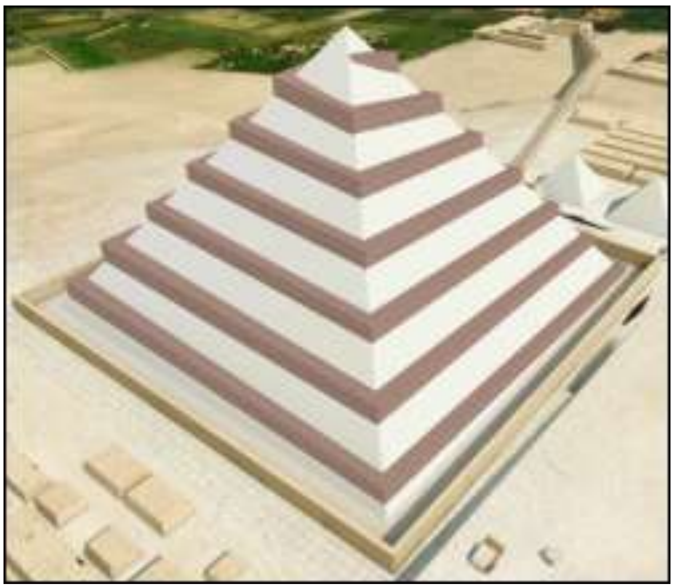
So the taller the ramp, the wider the base had to be. Even a ramp as wide as the base of the pyramid itself, at a seven percent grade, would only reach about 130-135 meters high, which is still eleven to sixteen meters shy of the apex. And once this ramp reached the wadi, the base would have to grow even wider as it extended downward.

This presents a second problem with straight ramp theories. Building a straight ramp that was one+ mile long over the wadi and through the quarry would require more building material than the pyramid itself. Of course, the project would have been less complex than the pyramid, so it would not necessarily have doubled the time or labor, but it *would* have more than doubled the material required and would have severely taxed Hemienu's schedule. And a ramp this large, which itself could have qualified for one of the Wonders of the Ancient World, raises a third question—where are its ruins?

Where could Hemienu have disposed of enough limestone blocks and filler material to construct a second Great Pyramid? Some theories contend that much of the ramp would have consisted of sand, which could have been spread out over the plateau when the ramp was dismantled. But some of the blocks transported up the ramp weighed in excess of sixty tons, which would have required a much more solid core for the ramp than sand.

Besides, the plateau is not as sandy as one might imagine. You needn't dig far before hitting bedrock, and gathering enough sand to fill a structure larger than the Great Pyramid would have presented more difficulties than are immediately apparent. Hemienu could have used limestone chips and scrap from the quarry, which takes us a little closer to how he actually *did* build the ramp, but again, where did he dispose of the ramp when the project was completed? There is simply no convincing archaeological evidence that a mile-long ramp as described above ever existed on the Giza Plateau.

We have already looked in detail at the problems of building the Great Pyramid with just a straight ramp in *Part One: How Do You Prefer Your Ramp?* But we also saw that there are advantages to using a straight ramp, some of which are indispensible. The only feasible alternative to a single straight ramp is one that would have spiraled around—or within—the pyramid. But spiraling ramps have their own limitations which exclude them as a singular solution to how the pyramid was constructed.



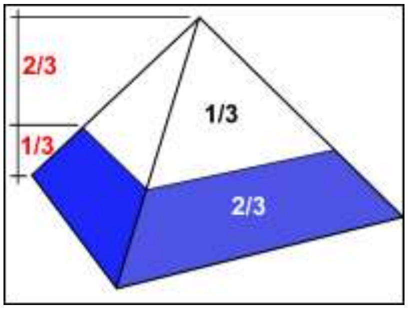
Again, please refer to *Part One: How Do You Prefer Your Ramp?* for the specific details of why a spiraling ramp alone would not have been sufficient in constructing Khufu's pyramid, especially during Phase One. For here, we will just say that an external spiraling ramp would have been structurally unsound and would have prevented the engineers from making the observations required for maintaining the pyramid's shape. And both internal and external spiraling ramps are excluded by one really big factor—the 60+ ton blocks of granite that were required to construct the King's Chamber could not have navigated the right angle turns.

In fact, the megalithic granite blocks pretty much demand that a straight ramp was used in some of the construction. So where does that leave us? It means that Hemienu needed a straight ramp that was short enough to fit into the terrain while maintaining a grade of 8—8.5 percent. The ramp also had to be wide and stout enough to bear the 60+ ton blocks at least to the 43-meter level, that of the King's Chamber. A 43 meter-high ramp could have been built that would have met these criteria while fitting into the limited space, but such a ramp would reach less than one third of the pyramid's final height.

This isn't quite the disaster it sounds like. The bottom third of a pyramid has some very useful geometric qualities that worked to Hemienu's advantage. He had been around for the construction of Pharaoh Snefru's pyramids and knew from the beginning what he was getting into and how to go about achieving it. His design for Khufu's Pyramid assured that every feature that required a straight ramp could be accomplished with one that only reached a third of the pyramid's total height. In essence, he could build two thirds of the pyramid with one third of a ramp.

The Bottom Third of the Pyramid and One Third of a Ramp

Hemienu was bound by the limits set by time, terrain, and materials. How was the Great Pyramid built within the 20-24 year timeframe which most Egyptologists agree on? How did the builders work within the limitations imposed by the terrain? How could it have been done with just the materials and tools for which we have evidence? Jean-Pierre Houdin's theory accounts for all of these conditions, beginning with the straight ramp.



So if it's true that the only straight ramp that could squeeze within all of these limitations would only have reached one third of the pyramid's total height (slightly less, actually), then how much of the Great Pyramid could Hemienu have built before needing to pursue a different strategy? This is where geometry was in his favor. Consider the nature of the pyramid as a three dimensional shape. If you were to build a four-faced pyramid out of sugar cubes, *by the time you reached the top of the first third in terms of* *__height__*, *two thirds of the total* *__volume__* *would be in place*.

As Jean-Pierre explains:

> The Egyptians…understood that the volume of a pyramid with a square base had an amazing property: for any value of the slope, the volume corresponding to one third of the height contains two thirds of the total volume." (Houdin, Khufu's Pyramid Revealed, p. 27)

So by the end of Phase One, Hemienu would have only been one third of the way finished in terms of *height*, but **two thirds** of the pyramid's *mass* would have been completed. This is not a bad investment of labor and materials—one-third of a ramp was sufficient to supply two thirds of the construction. In fact, once the King's Chamber and its surrounding core are factored in, the 43-meter-high ramp supplied more like **73% of the total volume of the Great Pyramid**. So in a certain sense, Hemienu actually accomplished nearly three quarters of the pyramid with one third of a ramp.

Another aspect of the Great Pyramid's design that maximized the usefulness of the one-third ramp is the fact that Hemienu located nearly all of the internal structures (that we know of) in the bottom third. The pyramid's entrance, the subterranean burial chamber, the Queens Chamber, the Grand Gallery, and all connecting passageways are below the 43 meter level. The King's Chamber would itself rise to nearly seventy meters, but its foundation (and worksite) was the surface of the 43 meter level. Thus, the straight ramp remained in use throughout both Phases One and Two.

Of course, the 43 meter-high ramp could not have moved the granite slabs or twenty-ton limestone rafters into their final positions above the King's Chamber, about seventeen meters higher than top of the ramp. As we shall see when we examine Phase Two, a sort of miniature pyramid was built on the surface of the 43 meter level to facilitate the construction of the King's Chamber, complete with ramps of its own. We will also get into the details of how the top two thirds (or one third, depending on whether we are talking about height or volume) were constructed when we take a look at Phase Three.

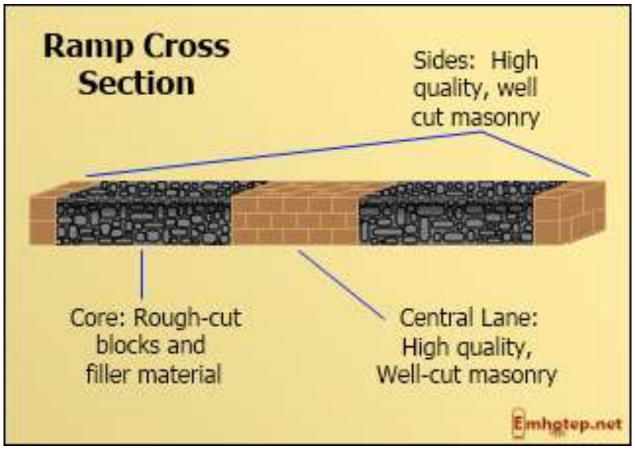
So let's now take a more detailed look at the external ramp of Jean-Pierre Houdin's theory, including how it would have been built and how it would have worked.

The Ramp

Materials

Before getting into the details of the location and orientation of the external ramp we should first explain what it was made of. In order for this to make sense, we need to jump ahead a little bit and discuss the structure of the ramp. The specific reasons for some of these details will be explained at length as we progress, but for now we will only be describing the materials from which it was constructed and how Jean-Pierre Houdin proposes it was assembled.

At its base the ramp would have been about 90 meters wide and divided into three lanes—a narrow central/dividing lane flanked by two wider side lanes. As we have already discussed, the ramp would have to taper as it went up in order to remain structurally sound, so with each layer the ramp rose in height, the lanes would have become narrower. In its earliest stages the ramp would have been mostly a horizontal causeway, sloping only at the foot. But just as the ramp would grow narrower as it rose, the sloping section at the foot would grow longer with each layer as the horizontal section became shorter.



In many ways, the external ramp mirrored the structure of the Great Pyramid itself. Like the pyramid, it had an outer layer of precisely cut blocks and a dense core of rougher blocks and filler. The central lane was an internal structure within the ramp, and like certain internal structures of the pyramid, served the sole purpose of transporting the heavy megaliths to the fiftieth level. The final layer of the central lane even had a pavement of Tura limestone like the facing stones of the pyramid. Using these materials was not just a matter of convenience, it was an example of Hemienu's foresight and a hint as to why the ramp left no ruins behind.

The outer walls of the ramp provided structure and stability, a sort of shell that contained the core. They would have been made of the same well-calibrated 2-ton blocks of locally quarried limestone as we see on the outer surface of the pyramid today. In the construction of each layer of the ramp, the sides and central lane would have been constructed first because they were more precise—the core could be made to fit them, but not the other way around—and because they served as a guide for how high to make the rest of the layer. They defined the boundaries of the lanes.

The core filled the area of the side lanes between the superior masonry of the central lane and the outer walls. The core blocks were cut from the same local quarry as the better-shaped blocks of the sides, but were not dressed to the same degree. They were not as uniform in size and shape, and no attention was given to making them fit together as seamlessly as the side and central blocks. The core blocks were packed in as closely as possible, and then limestone chips were poured into the spaces between blocks and pounded in tightly. Gypsum mortar was used to further cement the core into place.

The central lane was not just a divider between the side lanes, it was constructed with the final purpose of the external ramp in mind—supporting the sleds carrying the 60+ ton beams of granite up to the level of the King's Chamber. As stated above, the central lane was a sort of internal structure inside the ramp, the core of the core. It had to support the heaviest weights for the longest periods of time. The giant sleds bearing the megaliths were pulled up in forty-meter stretches and then had to rest while a counterweight system in the Grand Gallery was reset (much more on this in Phase Two).

The central lane was made of the same well-cut blocks from the local quarry as the sides of the ramp, but the final (fiftieth) layer of the central lane would have been paved with the imported limestone that was also used for the pyramid's facing stones, and then fitted with wooden rollers for the sleds. The local limestone contained hard little coin-shaped fossils of marine creatures called *nummulites* which caused its surface to be bumpy and pock-marked. The limestone imported from Tura did not contain these fossils and provided a smoother surface for the wooden rollers and their heavy burden.

All of the materials Hemienu used for the external ramp were recyclable—they could be reused in building the pyramid. The ramp was an early example of Green Technology, and the reason why there are no significant ruins of the external ramp. As we will see when we get into Phase Three, the pyramid "ate" the external ramp. When it was no longer useful it was dismantled, carried up through the internal ramp, and incorporated into the structure. Jean-Pierre theorizes that the external ramp remains hidden in plain view to this day as part of the top third of the Great Pyramid.

Orientation and Elevation

So now that we have an idea of what the ramp was made of and the basic architecture of one of its layers, where exactly does Jean-Pierre Houdin propose it was built? We have already seen that straight to the south was the shortest route to the wadi, but this was also the most level terrain. Wouldn't the flattest surface be the most ideal for the external ramp? Not necessarily.

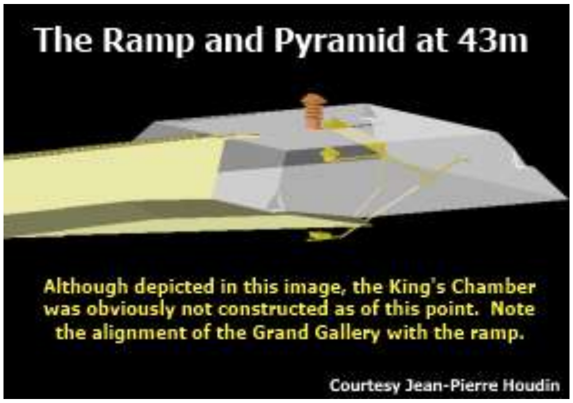
Jean-Pierre suggests that rather than building straight toward the wadi, Hemienu could have instead built the ramp at a twenty degree angle to the southwest where he could turn the uneven terrain to his advantage. The plateau continues to rise in a gentle upward slope in this direction, a characteristic Pharaoh Khafre made use of a generation later. By building on the higher ground, Khafre was able to make his pyramid appear taller than Khufu's. Jean-Pierre observes that by locating the foot of the ramp on this slope Hemienu could have built a shorter ramp without increasing the steepness of the incline.

There were other advantages to building in this direction as well. To begin with, a twenty degree southwestern trajectory would have both dodged the wadi and left access to the southeastern corner of the pyramid unimpeded, the importance of which will become apparent when we discuss the internal ramp (Phase Three). This angle would also have better aligned the ramp with the easiest route up from the quarry and the quay where ships delivered the Tura limestone and Aswan granite. But the real advantage came from the higher ground.

Situating the foot of the ramp on the southwestern slope meant that it would have been higher than the base of the pyramid, which would have achieved the opposite effect of building into the wadi. Instead of having to fill in all the terrain, some of the terrain would have been incorporated into the ramp. Of course, the gap formed by the lower terrain between the slope and the pyramid would have to be filled in, but Jean-Pierre demonstrates how even this could have been turned to Hemienu's advantage.

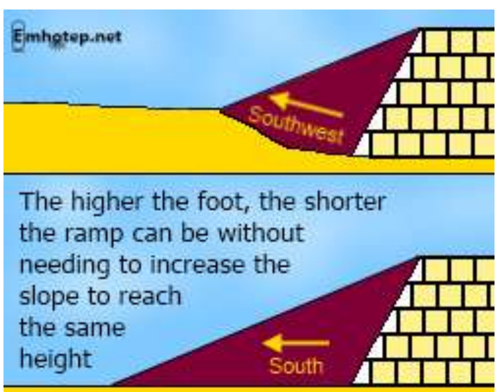
Jean-Pierre Houdin has calculated that a 43-meter high ramp built from the center of the southern face of the pyramid and oriented 20 degrees to the southwest would have its foot on a point on the plateau about eight meters higher than the base of the pyramid. With the foot of the sloping section of the ramp at this elevation, a 425-meter long straight ramp would extend from the foot to the apex at an incline of around 8.5 percent, which is within the range of an ideal slope. That is admittedly a lot of numbers, angles, and directions for one paragraph, so let's break it down into manageable parts.

Deconstructing the External Ramp



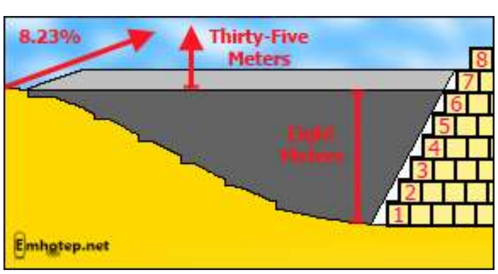
Forty-three meters high is a *magic number* because that was the level at which construction began on the King's Chamber, the pyramid's *raison d'être*. Recall that the primary need for a *straight* ramp was to avoid right angle turns while transporting the megalithic blocks of Aswan granite up to the level of the King's Chamber, so the straight ramp had to be *at least 43 meters high*. Any higher was unnecessary because after the King's Chamber was finished, all other building materials could come up through the internal ramp (except the pyramidion, but we will cover that in Phase Three).

The center of the southern face of the pyramid is a *magic spot* because locating the top of the ramp here lines it up with the Grand Gallery. The importance of this will become clear when we examine Phase Two, but for now we will just say that the enormous beams used in the building of the King's Chamber were pulled up with the assistance of a counterweight system located in the Grand Gallery. This could only work if the apex of the ramp was aligned with the Grand Gallery. We will get into the details of how the 20-degree angle of the ramp was negotiated when we get to Phase Two.

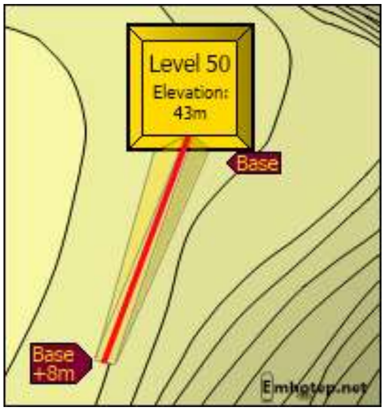


Twenty degrees southwest is a *magic angle* because building the ramp in this direction located the foot on the higher ground where the plateau continues to rise, whereas due south the plateau begins to *decline*. Building on higher ground helped mitigate the need to build as short a ramp as possible with the need for the shallowest slope possible because raising the low end of a diagonal without changing the height *or* the slope means a shorter ramp. Thus, locating the foot of the ramp on the incline meant a shorter ramp while still being able to keep the grade at 8—8.5 percent.

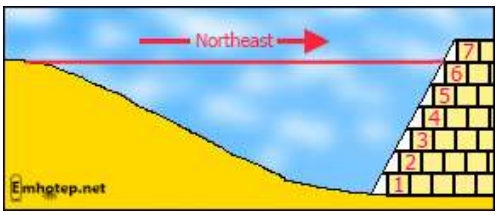
The 8—8.5 percent grade is a *magic slope* because, as we have already noted, the more gradual the slope, the longer the ramp has to be, and the steeper the slope the more effort that is required to haul the 2-ton blocks up the incline. Hemienu wanted to keep the supply chain of blocks moving at maximum pace. Ideally, as a block was finished in the quarry at one end of the chain, a block should be fitted into place at the opposite end. This meant Hemienu wanted room for as many teams on the ramp as possible, and an 8—8.25 percent grade allowed for small teams of ten to twelve men.

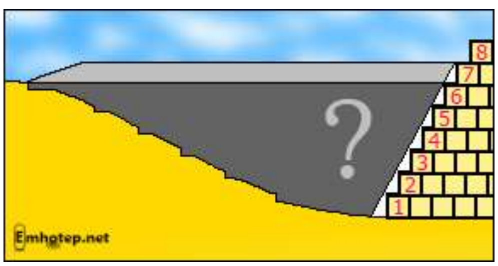


Four hundred twenty five meters is a *magic length* because at this distance the foot of the ramp hits the southwest slope at an elevation of eight meters higher than the foot of the pyramid. ***Eight meters*** is a *magic elevation* because starting the sloping section of the ramp at this height means that the vertical height from the (sloping) foot to the apex would be 35 meters (*43 – 8 =35*), and a 425 meter long ramp that ascends 35 vertical meters would have an incline of 8.24 percent (*35/425 = .08235*), which is within the range of the *magic slope*.



So let's summarize. If you were to sit at the middle of the southern edge of the fiftieth course of the pyramid (the 43-meter level), right where the top of the ramp would be, and shine a laser pointer twenty degrees southwest at an 8.24 percent downward angle, the red dot would hit the southwestern slope at an elevation about eight meters higher than the base of the pyramid. If you were to point the laser due south at the same downward angle, the beam would be longer because the terrain is lower. To the southwest the terrain rises to meet the beam. To the south it declines away.





Now let's say that you climbed down the pyramid and hiked over to the spot on the southwestern slope where your laser beam had pointed. If you then directed the beam northeast toward the pyramid at a horizontal trajectory, the red dot would hit the pyramid at 8 meters above the base, at about the top of the sixth course of blocks. The beam would be about 425 meters long, thus establishing the full length of the longest horizontal layer of the ramp.

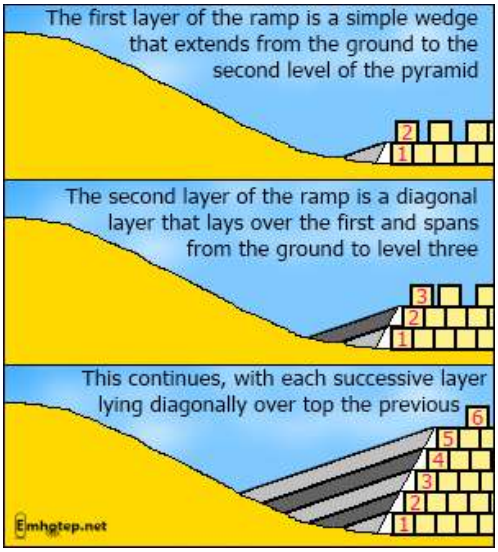
This raises a new line of inquiry. Obviously, no ramp was needed to build the first course of the pyramid—it was at ground level. As the graphic to the left shows, the seventh level of the pyramid would have been constructed using the horizontal layer (dark grey) that forms the base of the first sloping layer (light grey), which in turn would have been used to build pyramid level eight. But what about pyramid levels two through six?

<u>A Ramp of Tiers</u>

There are basically two ways Hemienu could have built a straight ramp that was able to grow with the pyramid, and both types involve building successive layers of the ramp to reach the pyramid levels under construction. One type would have consisted of diagonal layers each of which sloped all the way from the ground to the face of the pyramid. The other type would have been constructed of layers of horizontal tiers that only sloped at the foot-end. Again, this is easier to say than visualize, so let's break this down too, starting with the diagonal ramp.

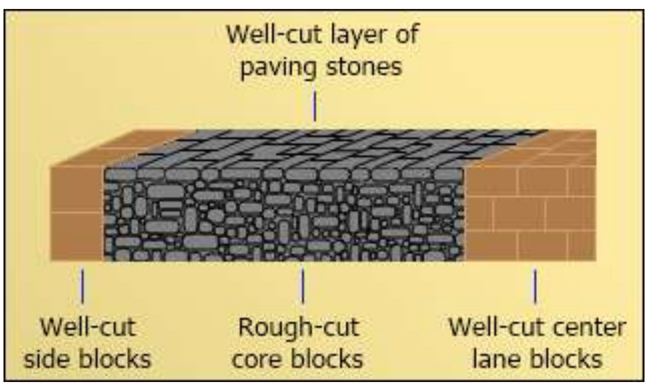
But before we continue, let's take a moment to clarify some of the terminology we will be using. Since both the ramp and the pyramid consist of layers of construction, it is easy to get confused by statements such as *the second layer of the ramp was used to build the third layer of the pyramid*. For this reason, *layers of the ramp* will always be referred to as ***layers*** or ***tiers***, and *levels of the pyramid* will always be referred to as ***levels*** or ***courses***.

Thus, *layer* or *tier* X will always refer the <u>ramp</u>, and *level* or *course* Y will always refer to the <u>pyramid</u>. We will have to adapt this system in *Phase One, Part B*, when we begin dealing with the facing stone and backing stone layers of the pyramid, but for now, *layer* refers only to a layer of the ramp, not pyramid blocks. It is also helpful to remember the equation ***ramp layer* X *is used to build pyramid level* X+1**. In other words, ramp layer 2 (X=2) is used to build pyramid level 3 (X+1).



With that out of the way, let's now take a look at the structure of a diagonal ramp. Diagonal ramps take the most direct route—a sloping surface straight from the ground to the level under construction. So once the first level of the pyramid was complete, the first layer of a diagonal ramp would have been a simple wedge from the ground to the top of the first course of blocks. When the second course was finished, then a new diagonal layer would have been built on top of the first, again stretching from the ground to the work site. This would be repeated until the fiftieth pyramid course.

But there are some problems with this design. One structural issue is the amount of pressure directed at the foot. With diagonal layers, the weight of the ramp is directed downward and outward, and the higher the ramp goes the more pressure that is pushing down against the foot. This is not a major problem for a ramp with an 8.24 percent grade—most of the weight would still be directed downward rather than against the foot. But keep in mind that the final layer of the ramp, the fiftieth, was not only the longest and heaviest; it was also the layer that bore the 60+ ton granite slabs.

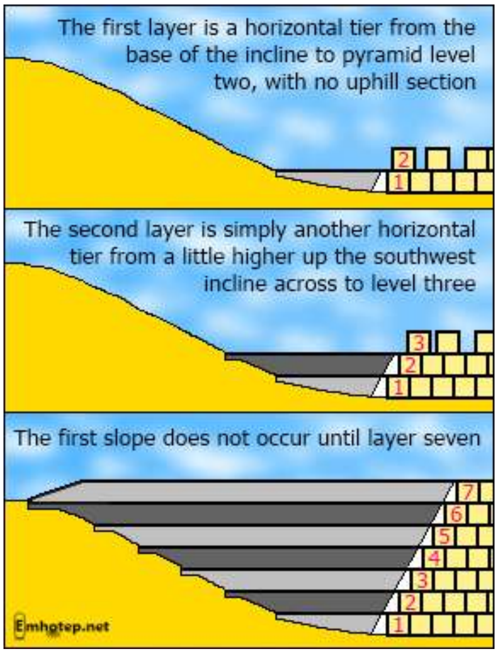


A more nagging problem would have been the paving. As already noted, the blocks used to build the side lanes were rough-cut stones packed in with filler. But the top surfaces of the side lanes—the surfaces over which the two-ton blocks were transported—would have been made to a higher standard. While probably not as well-cut as those of the sides and central lane, and certainly nothing like the Tura limestone that would cover the final layer of the central lane, the top surfaces of the side lanes would nonetheless have been smoother and more durable than the rest of the core blocks.

This layer of higher-grade paving stones was especially important on the sloping part of the ramp. As mentioned above, the pressure of the weight on an incline is distributed downward and outward, which on Hemienu's ramp would have been largely mitigated by the very shallow incline—an 8.24 percent grade is directing most of the weight downward rather than outward. But the reality of movement on the ramp was more complex than just this. Not only was there the gravitational pull on the sleds, there was also the foot pressure of the pullers seeking traction and the forward pressure of the sleds in motion.

So the cycle of movement/pressure/weight on the diagonal surface would have been the downward and outward foot pressure of the teams pulling the sleds, the downhill gravitational pull on the sleds between tugs, interspersed with bursts of uphill gouging-type pressure from the rails as the sleds in motion met the resistance of the surface of the ramp. That is an awful lot of multidirectional jarring from millions of tons of traffic over years of use, so the pavement on the diagonal surfaces had to be pretty tough.

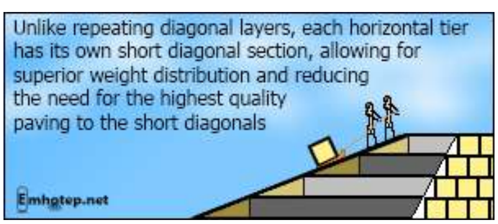
A ramp constructed of repeating diagonal layers would have required this high-quality pavement over the top surface of every layer of the side lanes, one through fifty, from foot to apex. Although the inner core could be rough, the traffic-bearing uphill surfaces would need this layer of paving, and on a diagonal ramp, *every outward facing surface is uphill*. But a ramp of tiers would consist mostly of horizontal surfaces, which means better weight distribution, less effort for the pulling teams (and thus, less foot pressure on the surface), and smoother movement of the sleds over the pavement.



Jean-Pierre believes that Hemienu would have opted for a ramp of horizontal tiers rather than diagonal layers. Instead of the first layer being a diagonal wedge, Jean-Pierre proposes that it was a simple tier which extended from the face of the pyramid across to the foot of the southwestern slope at a constant height equal to that of the first level of the pyramid. To construct the second level of the pyramid, the builders would have pulled their sleds down the southwestern slope and *across*—not up—the first layer of the ramp. The second layer of the ramp would have been another horizontal tier atop the first.

This answers the question of how the ramp serviced levels two through six of the pyramid, even though the foot was situated eight meters higher than the base. The foot of the *sloping section* of the ramp was located at the higher elevation—parallel to the seventh pyramid level—but the first six layers of the ramp were horizontal tiers with no slopes. This implies another advantage of a ramp of tiers over a diagonal ramp. The first six courses of the pyramid, about 14.5 percent of the total volume, were constructed without any uphill sections. A diagonal ramp would have been continually uphill.

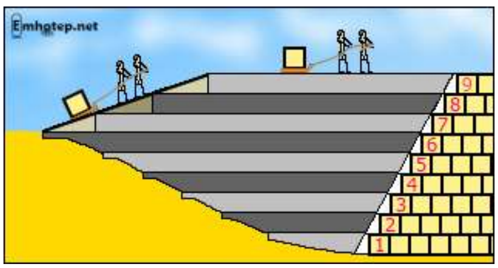
Yet another advantage of a ramp of tiers is its superior foundation. Unlike a ramp of diagonal layers, every layer of a ramp of tiers rests on a flat surface. Although the chance of slippage between layers on a diagonal ramp with an 8.24 percent grade are negligible, with a ramp of horizontal tiers it is eliminated entirely. Of course, there would still be the short diagonal sections at the foot of each layer, but the surface beneath these sloping sections would be flat rather than another diagonal.



Starting with the seventh layer of the ramp, each horizontal tier begins with a short sloping section at the foot-end, but these wedges are structurally superior to the long sloping stretches of a ramp of diagonal layers. Although from the outside the ramp appears to have a single diagonal surface that grows with each layer, in reality each wedge-shaped section functions more like an individual ramp resting on its own horizontal foundation. Unlike a long diagonal layer, each wedge bears the weight above it individually, with virtually no transference of pressure to the sections above or below it.

As mentioned above, this configuration would also reduce the amount of paving required for the side lanes. Superior weight distribution, reduced foot pressure due to the sled teams pulling on a flat surface rather than an incline, and less wear and tear from forward and backward jerking of the sleds, again due to a flat surface rather than an incline, meant that the paving on the horizontal sections did not have to meet the same demands as the diagonal slopes. The short diagonals would still require the superior pavement, but the total diagonal surface would be equal to just the final layer of a diagonal ramp.

So a ramp of horizontal tiers would have been advantageous to Hemienu in many ways.   The amount of uphill pulling would have been minimized. In fact, building the six largest levels of the pyramid would have been a straight shot across with no uphill section of the ramp at all. The uphill section would grow from the seventh layer to the fiftieth as both the ramp and the pyramid grew, but as the diagonal got longer and the horizontal sections got shorter, the layers of the pyramid were getting smaller too.



A stack of horizontal tiers is more solid than diagonal layers. The base of all sections of the ramp, even the upward-facing diagonals, would be a flat surface. Layers one through six may have been partially extended onto the bedrock, but from level seven upward each layer would rest on a horizontal surface equal in length to its base, with nothing ever built over top of a sloping section. With regard to paving, the total area of a ramp of tiers that would require the highest quality paving would equal to just the final layer of a diagonal ramp. A lower-quality paving would suffice for the horizontal sections.

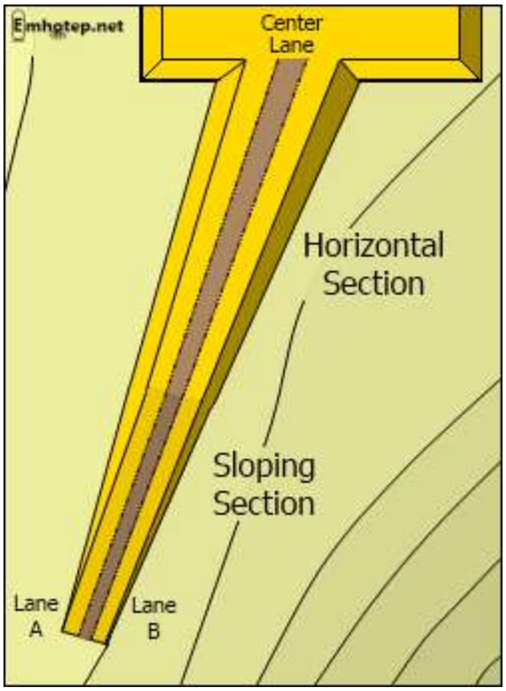
So we have examined why Jean-Pierre Houdin thinks Hemienu would have built the straight external ramp twenty degrees to the southwest. It allowed him to use the incline to situate the foot of the *diagonal section* of the ramp about eight meters higher than the base of the pyramid, which meant a shorter ramp while still keeping the grade below 8.25 percent. We have seen that levels two through six of the pyramid were built using horizontal sections of the ramp as it slowly filled the gap between the pyramid and the southwestern slope, rising level by level like water filling a bowl.

So far we have not examined why the ramp described by Jean-Pierre has three lanes. We know the central lane was to support the sleds bearing the heavy granite beams to the King's Chamber worksite in Phase Two, and naturally, having a central lane implies side lanes. But the side lanes were not simply a result of dividing the ramp with a central structure, they were an essential part of the plan. The two side lanes were an innovation designed to address another problem ignored by traditional ramp theories.

In most theories of how the Great Pyramid was built, all work on the pyramid has to stop at the completion of each level while the ramp is built up a layer. The architect Jean-Pierre suggests a way such stoppages could have been avoided, which he proposes the architect Hemienu would also have realized. The three lanes of the external ramp were actually three ramps in one.

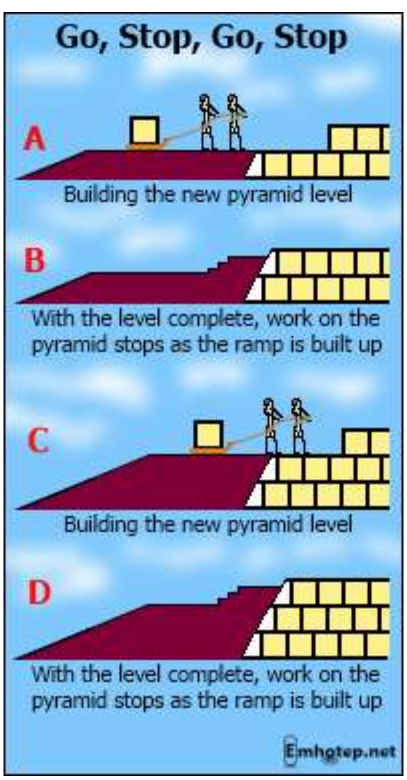
A One Third Ramp that was Three Ramps in One

We have seen that the external straight ramp described by Jean-Pierre Houdin's theory could be called a "one third ramp" because it only reaches *one third* of the final height of the pyramid, but we have also seen that this would have been sufficient to construct *two thirds* of the actual mass of the pyramid. There would have been additional ramps constructed on the top surface during Phase Two in order to maneuver the huge granite and limestone beams into place above the King's Chamber, but the 43-meter-high straight ramp would have been the means of delivering them to the worksite.



But the external ramp of Jean-Pierre's theory could also be called "three ramps in one." Since a "one-third-ramp-that-was-three-ramps-in-one" sounds like something out of *Alice in Wonderland*, we will continue to refer to them as lanes, but to a certain degree each lane functioned independently of the others. The central lane would not come into service until layer fifty, and we know that the side lanes would carry all of the traffic until then, but for layers 1—34 only one of the side lanes would be in use at any given time (we will get into the details of what happens at layer 35 in *Phase One, Part B*).

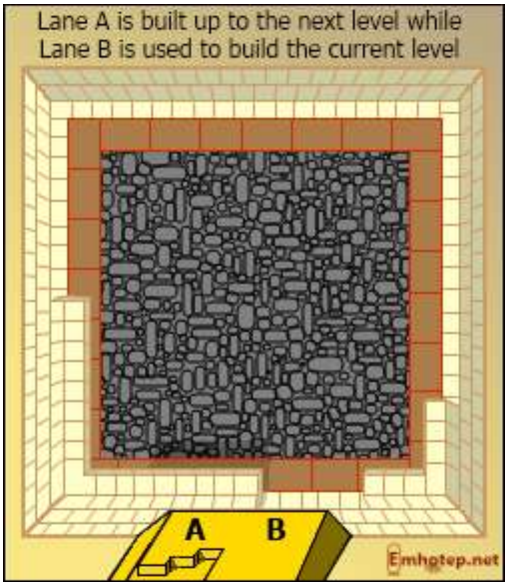
One of the unique features of the ramp described by Jean-Pierre's theory is that prior to layer 35 the central lane and one of the side lanes were always under construction while the opposite side lane was used to service the pyramid level currently being built. The active lane would alternate from left to right and back again with each successive level of the pyramid. This pattern was the key to how work on the pyramid could continue uninterrupted for the duration of Phase One.



Most ramp theories require a go/stop work cycle for building the levels of the pyramid:

A. Build a level of the pyramid and then stop
B. Build the ramp up a layer and then stop
C. Resume work on the pyramid until the new level is finished and then stop
D. Resume work on the ramp, building it up a layer and then stop.

Repeat.



But these work stoppages were unnecessary. As shown in the figure to the left, while Lane B is used to build the current level of the pyramid, Lane A is being raised up from the previous layer to the same layer as B. But once Lanes A and B are at the same layer, work continues on Lane A, raising it a second layer in preparation for the next pyramid level. Thus, once the pyramid level is finished Lane A will already be in place to begin work on the next level, the workers simply switch from Lane B to Lane A. Lane B is then built up two layers in preparation for the next pyramid level.

And again we have a paragraph packed as tightly as the ramp's core with difficult concepts to visualize! Fortunately the next chapter, *Phase One, Part B*, is dedicated entirely to the concept of the alternating lanes and how the pyramid was "built from the inside out." We will start by constructing a model of how the ramp was used to build the first two levels of the Great Pyramid, followed by an in-depth look at the construction of level three to see what is meant by "building from the inside out." We will conclude Part B with a look at what happens at layer 35, why it happens, and how it was resolved.