Pavement Design at Coast Guard Air Station Clearwater

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United States Coast Guard Air Station Clearwater is the largest and busiest aviation unit in the Coast Guard recording more flight hours than any other air station. The current condition of the air station pavement is poor and work is ongoing to improve the material condition of parking aprons and taxiways where the aircraft transit. A U.S. Coast Guard Academy Cadet Capstone team has been tasked to design repairs and reconstruction for these areas to accommodate a C-130 aircraft as well as the newly Coast Guard acquired C-27 aircraft. The project design and construction will follow the requirements set forth by the Unified Facilities Criteria (UFC) and the Federal Aviation Administration (FAA). Additionally, pavement reconstruction, repair, and future maintenance will be coordinated to ensure continued operations at the air station. PAVER software will be used to develop a pavement management database so the long-term performance of the pavement sections can be monitored over time. Finally, considerations will be made with relation to how reconstruction designs will impact the water runoff.

Introduction

The United States Coast Guard Air Station located in Clearwater, Florida is one of the busiest aviation units in the Coast Guard. The operational status of this unit is of the utmost importance to ensure a prompt response to maritime emergencies. Therefore, the material condition of the pavement is critical. With failed pavement, aircraft may not be able to operate out of Clearwater, which would result in delayed response time and a danger to the public. While considering the extensive damages to the pavement, the Capstone design team must also keep in mind that the air station is acquiring new C-27 aircraft. As a result, traffic density will greatly increase in the near future. With this in mind, the pavements will be designed to support the C-130 and the newly acquired C-27.

Directed by the U.S. Coast Guard, the cadet Capstone conducted a site visit to assess the condition of apron and taxiway conditions. Based on the assessment, the team is establishing new designs to reconstruct or repair Hot Mixed Asphalt (HMA) and Portland Cement Concrete (PCC) sections including the taxiway and aprons on which the aircraft park. By utilizing PAVER, a pavement management program widely used by pavement engineers, the team is able to track which pavements include the most severe damage along with the historical design and construction information. This information will be used to develop a maintenance plan that will be implemented by the air station's facility engineer.

The Coast Guard belongs to the Department of Homeland Security, which proves difficult when ascertaining what doctrine governs over construction for the designs. To remedy the situation the team looked at two different organizations; the FAA and the UFC. Both organizations set forth dissimilar limitations on pavement design and practices for airports. The Department of Defense uses the Unified Facilities Criteria (UFC) for construction codes and practices making it relevant for another military branch to follow the same standards. Since the Coast Guard does not fall under the Department of Defense and Coast Guard Air Station Clearwater is collocated with a public airport there has been a tendency for the Coast Guard to follow public airport standards from the FAA. With both doctrines in effect, the team will go by the most conservative limitations set forth by either doctrine to ensure compliance with standards, and ensure the safest possible designs.

Environmental impacts and water runoff from the pavement design will also be considered. Options for additional pavement areas may be an option which may cause additional accumulation of water as well as increased runoff. This water accumulation reduces the pavement service life and leads to the buildup of debris including rocks and gravel which damage the aircraft blades. To address the potential for additional runoff and standing water, the team will conduct a storm water analysis and implement design methods including crowning to minimize the effects of run-off onto the aprons and taxiway. Pervious pavement will also be explored as a potential design solution to address runoff issues.

Design Alternatives

The reconstruction design for HMA, below is the design method for the mill and overlay of the taxiway and any other HMA section to be milled and overlaid. There is rutting in the taxiway pavement along the tracks of the wheels of the aircrafts. This damage is an indication of a faulty surface layer as opposed to faulty base and sub base layers. Therefore a mill and overlay is viable option as long as the pavement is well maintained. The mill and overlay of the taxiway HMA will require removal of two inches of the surface layer and a replacement of those two inches with new P-401 asphalt, as recommended by the FAA. The current surface layer, as per the given designs, is four inches thick. Therefore, removing only two inches avoids the possible issue of partially removing and disrupting the base layer. The total minimum thickness was found from a UFC chart which considers the CBR, aircraft type, and number of annual passes, and the traffic type, this specific section being a taxiway. To find the CBR, the original construction as-builts were reviewed. The soil is classified as a SP-SM soil. A CBR of 10 was calculated using Figure 2 below. This minimum value was used for the design to ensure the safest possible design.

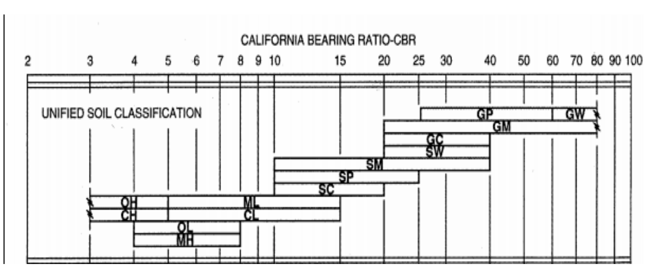

Figure 1 UFC Manual CBR guide

From the UFC Figure 10-4F, it was found that the total necessary thickness was 18 inches which concurs with the current total thickness of 20 inches. As given in Table 2, the minimum thickness of the surface is four inches. The current surface thickness is four inches, and the current base layer is six inches which concur with the minimum thicknesses given in Table 4 below, which is in accordance with the Army standards. Therefore, these thicknesses will be in accordance with the UFC, and a mill and overlay is sufficient.

Table 1 Minimum thickness requirements from UFC

		100 CBR Base			80 CBR Base[1]		
Airfield Heliport Class	Traffic Area	Surface	Base	Total	Surface	Base	Total
I	B	2	6	8	2	6	8
II	B	2	6	8	3	6	9
III	A	2	6	8	2	6	8
	B	2	6	8	2	6	8
	C	2	6	8	2	6	8
IV (Runway ≤ 5,000 feet)	A	4	6	10	5	6	11
	B	4	6	10	5	6	11
	C	3	6	9	4	6	10
IV (Runway > 5,000 feet)	A	4	6	10	5	6	11
	B	4	6	10	5	6	11
	C	3	6	9	4	6	10
IV (Runway ≥ 9,000 feet)	A	4	6	10	5	6	11
	B	4	6	10	5	6	11
	C	3	6	9	4	6	10
V	B	2	6	8	3	6	9

The HMA areas located between the C-130 aprons vary in condition. The HMA sections to be analyzed are all located in between two patches of grass and therefore were evaluated separately. In Figure 1 below, the aforementioned sections are; 300, 301, 302, 303, and 304. Due to the different conditions, three separate options were considered for redesigning these areas. The first option is using fog sealant over sections 300, 303 and 304. This is because the area displayed only weathering. While fog seal is a useful way to seal weathered, oxidized pavement, or pavement containing small cracks, the FAA warns that this type of surface treatment is typically limited on airfields due to decreased friction, debonding, and raveling of the asphalt. Furthermore, in order to stay intact the seal would have to be reapplied every 2-4 years. Therefore, with aircraft safety and minimizing the maintenance burden for the facility engineering being top priorities more repair options were considered.

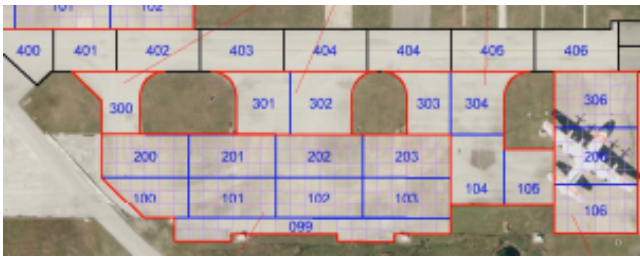

Figure 2 Air Station pavement sections

The second option discussed for the HMA sections, was to mill and overlay sections 300, 303, and 304 along with the taxiway which requires a mill and overlay as discussed below. This would result in a more continuous construction process, for the mill and overlay could occur at the same time as that of the taxiway. With a mill and overlay along with the other pavement, it would ensure a similar service life and simplify maintenance coordination. The sub grade and sub base for these areas are the same as the taxiway, and the traffic encountered are predicted to be the same as well. Therefore, the design methods for the sections are similar to what is discussed above for design of the taxiway. Areas 301 and 302 have to be completely reconstructed due to the significant cracking in these sections. The base and sub base would have to be torn up and reconstructed, because the types of cracks recognized on these sections are caused by failure of the lower layers of the pavement, and not simply the surface layer. This will also ensure a better service life to support the loads in those areas. The design method for the complete reconstruction is described below.

The third option that was considered for these specific areas includes the removal of the grass areas shown in between section 300 and 301 and in between 302 and 303 to provide more turning room for the aircrafts. This would result in the complete reconstruction of these pavement sections. Since construction will already be occurring on the adjacent taxiway this additional construction is not unreasonable. This option includes the reconstruction of areas 300, 301, and 302 with mill and overlay of 303 and 304. In order to maintain adequate drainage, not all of the grass areas would be removed, but partial removal will improve the aircraft turning radius. The reduced grass area will increase runoff so the impact of this design is discussed in the watershed management section below. The final option simply is to reconstruct all of the area including the taxiway, but is the most costly, and evaluated as unnecessary.

For the full reconstruction design of the HMA sections, the Unified Facilities Criteria design tables were utilized. The sub base material should be a naturally occurring coarse-grained soil. The base course material is to be Limerock which is prevalent in this region of Florida and therefore will be easy to acquire. The design California Bearing Ratio (CBR) for Limerock given from the UFC is 80, as shown in Table 1.

Table 2 shows the design CBR values based on the base course material.

Aggregate Base Course	Design CBR
Graded Crushed Aggregate	100[1]
Aggregate[2]	80
Limerock	80
Shell Sand	80
Coral	80
Shell Rock	80

The minimum recommended surface and base course thickness are given in the UFC manual. The tables are separated by Military Service and the Navy standards were selected as these are stricter standards. The minimum values for the C-130 and C-27 loading are a surface thickness of 4” and a base course thickness of 8”. Furthermore, UFC Figure 10-4F, considers CBR value, aircraft weight, number of passes, and airfield type gives a minimum thickness of 18 inches.

Table3 Minimum pavement surface and thickness requirements from UFC (Navy)

Aircraft Gross Weight kg (kips)	Tire Pressure MPa (psi)	Minimum Thicknesses, mm (in.)		
		Surface	Base[1]	Total
< 5,440 (<12)	All pressures	50 (2)	152 (6)	203 (8)
5,440 to 13,600 (12 to 30)	<1.38 (200)	76 (3)	152 (6)	228 (9)
5,440 to 13,600 (12 to 30)	1.38 (200) or greater	102 (4)	203 (8)	305 (12)
>13,600 (>30)	All pressures	102 (4)	203 (8)	305 (12)

Table 4 a design summary of the reconstruction of the HMA pavement cross section.

	Minimum thickness	Current thickness	New thickness	Change?
Subbase	6"	10"	8"	Yes
Base	8"	6"	8"	Yes (to meet minimum)
Surface Layer	4"	4"	4"	No
Total- base, subbase, and surface layer	18" (From chart)	20"	20"	No (need to keep same level as the rest of the airstation)

Furthermore, Recycled Asphalt Pavement (RAP) was looked at for this project in order to make it more cost effective and sustainable. Unfortunately, the updated draft of the UFC manual states that recycled hot-mix asphalt millings "should not be used for HMA surface course," and RAP therefore cannot use a be used for the mill and overlay process of any of the HMA, as the mixture would not be safe enough for a pavement that will encounter such large loads.

For the Portland Cement Concrete reconstruction design, The FAA and UFC rigid concrete design guidelines were reviewed as well, and hand calculations were completed using the UFC manual and the appropriate charts provided in the manual. These hand calculations were then checked using the FAA online rigid pavement design calculator.

When using the online aid from the FAA, several inputs were required to determine the new required thickness of the PCC. First, the thickness of the sub base aggregate layer was inputted, which was determined to be eight inches from the drawings provided by the facilities engineer. The next value entered was the foundation of modulus, also known as the k value, for the S, which was found to be 120 psi. The sub base at the airport, as mentioned in the above analysis, is SP-SM, and designated to have a k-value of 120 psi at the sub base level. These assumptions are therefore made for the project since no exact value could be found in the plans provided from a soil analysis. Next, the specifications for the new concrete were input into the software. 650 psi was used for the new flexural strength of the concrete, 0.15 for poisson's ratio, and 4,000,000 for the modulus of elasticity. All of these values were obtained from the UFC manual and the specifications provided. No less than 650 psi is acceptable for airports and it is the most easily obtained strength in the field. Poisons ratio and the modulus of elasticity were both also specified in the manual. Finally, aircraft information was inputtedt for the design of the area. Since the Coast Guard is phasing out C-130s and phasing in C-27s a determination had to be made as to which aircraft would dictate the design of the area. The C-130 is much heavier and would yield the worst case scenario; therefore this use of this aircraft was used for all calculations as a factor of safety. Air Station Clearwater, is preparing for the phase out of the C-130s in the next couple of years, however, designing for the worst case scenario was pertinent for the air station as the construction will most likely take place prior to the new aircraft being present. Traffic at Air Station Clearwater was determined to have no more than 2,000 annual departures and the maximum takeoff weight of the C-130 was calculated to be 155,000 lbs. There was also an option in the software to design for frost conditions, but being in Florida and analyzing the historical forecast data there was no need to design for frost conditions.

With these inputs the software provided key outputs for the design of the rigid pavement area. Fist, it calculated the k value on the top of the stabilized layer to be 184 psi; a value around 200 was needed to satisfy the UFC specifications. Also, it calculated the overall PCC thickness needed to be 10.5 inches. The design output can be seen in the following image. A frost depth penetration was calculated for this design using the program however, this value was not necessary for the geographical location of the air station.

Rigid Pavement Design For			*AC Method*
Airport Name:	Air Station Clear Water	Date:	2/29/2016
Associated City:	Clearwater, Fl		
Design Firm:	United States Coast Guard Academy	Designer:	Team Sass
AIP Number:	3-XX-XXX-XX		
New Pavement Section Required			*Stabilized Subbase Is Required*
10.5	PCC Thickness	650 psi	New Concrete Flexural Strength
0.0	Stabilized Base		
8.0	Subbase		
0.0	Non-Frost Layer (free draining material)		
			Large Aircraft Parallel to Joints (standard design)
Overlay Sections			
N/A	Asphalt Overlay Thickness	N/A	Existing Slab Thickness
N/A	Unbonded PCC **without** leveling course	N/A	PCC needed for existing sectio
N/A	Unbonded PCC **with** leveling course	N/A	Existing Stabilized Subbase
N/A	Bonded PCC	N/A	Existing Aggregate Subbase
		N/A	Existing Slab Flexural Strength
		N/A	F- Factor used in design
		N/A	Cr Factor
		N/A	Cb Factor
Frost Considerations (for new pavement section)			
Dry Unit Weight of Soil (lb/cf)	100		
Degree Days °F	250		
Soil Frost Code	Non-Frost		Subgrade k-value was not modified for fro
Frost Depth Penetration (in)	22.53		
k value on top of stabilized layer	184		
k value on top of subbase layer	184		
Original subgrade k value	120		
Design Aircraft Information			
C-130		20	Design Life (years)
155000 lbs	Gross Aircraft Weight		
2,000	Equivalent Annual Departures		

Figure 3 FAA Rigid pavement output

With the value recommended from the spread sheet, a hand calculation was needed to verify the values from the FAA output. This was crosschecked with the more commonly used manual for military air stations, the UFC. Both UFC and FAA are standards used at airports across the nation. By using both references a comparison can be made as to the most appropriate solution for this design.

The UFC has multiple charts to assess the thickness of PCC and as previously stated the design parameters for a C-130 governed the design. Figure 4 below shows the C-130 and Navy design requirements used for the hand calculations.

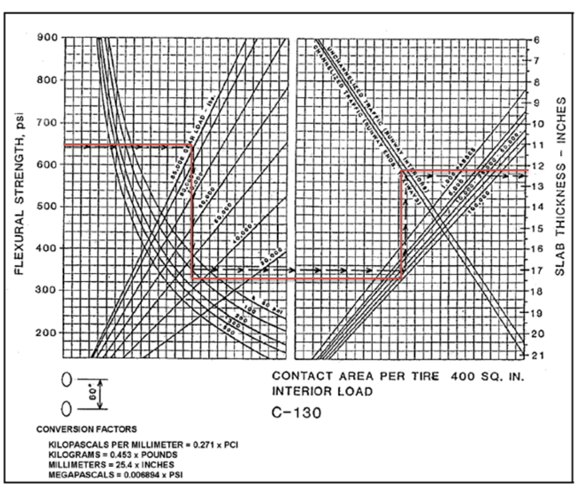

Figure 4 Rigid pavement thickness design C-130 (Navy)

The inputs required for the chart used for the hand calculation portion of the rigid pavement design are as follows.

- Flexural strength 650 psi just as in the FAA software.
- Gear load of the C-130 is 84,000 lbs as defined by the UFC table.
- The soil, has a k-value of 120 psi at the sub base.
- The total number of passes per year was calculated to be 2,000 and over a 20 year design life is 40,000 passes.
- A secondary traffic area was used because it is not one which is used for takeoffs or landings.

With these inputs the design thickness of the PCC was calculated to be 12 in. With the two values obtained for the recommended thickness of the PCC the area was designed to have a PCC thickness of 12 in.

From here reinforcement was determined to be needed for the rigid concrete. Based on UFC requirements slabs were decided be 12 by 15ft. With this No. 8, 20 in long, Dowels will be usedon all four sides of the slabs spaced 9 feet apart in each slab leaving 3 ft on either side in one direction and 6 ft apart on the other side with a 3 ft cover on either side. Dowel placement in the slabs will be just above mid-depth and were calculated to be at 6.5 inches from the bottom of the PCC.

Reinforcement is also needed in the longitudinal and transverse direction, to be placed slightly above mid-depth of the slab. After hand calculations were done, it was determined that to ensure an area of .16 in^2/ft is maintained we will use 4 inch by 4 inch spacing with a W5.5 by W5.5 rebar.

When developing the PCC rigid pavement design there were several factors to take into consideration. It was evident during the site visit that certain PCC areas require complete reconstruction. For example, there is significant alligator cracking and other structural failures of the concrete in the area behind the aprons where the C-130s are parked.

During the design process, the team weighed the cost of labor, materials and logistics heavily in the overall analysis of the pavement design and repair methods. A budget of $300,000 was employed to follow the guidelines of an annual Florida state grant for airport maintenance. This grant would supply the funds to reconstruct areas of the pavement but would have to be used in phases. The construction of the PCC and HMA is too costly to be considered within one grant, therefore reconstruction and repairs will be prioritized into different construction projects to address all the issues and make effective use of the grants. To accurately account for the cost of the labor, materials, and logistics the team used RS Means Heavy Construction Cost Data 26th ed. and the RS Means Buildings Construction Data 70th edition. The team also contacted the local asphalt plant close to Clearwater for cost information and compared it to the values determined from the RS Means. The plant's estimate for the proposed taxiway repairs confirmed the estimates ascertained via RS Means.

Analysis

The analysis process included several different factors. One of which being the pavement design software, PAVER. PAVER software has multiple capabilities including "developing and organizing pavement inventory, assessing the current condition of pavements, developing models to predict future condition, reporting on past and future pavement performances, developing scenarios for M&R based on budged or condition requirements, and finally planning projects" [1]. Specifically, PAVER has been used thus far to determine a Pavement condition index for the pavement. The Pavement Condition Index scales the pavement condition on a numerical scale ranging from zero to one hundred to assess the condition of the pavement section as well as the maintenance needs for the following years [1].

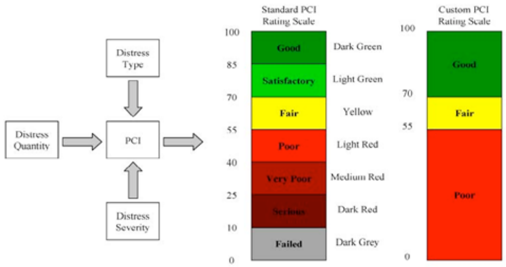

Figure 5 PCI Example

The PCI scale allows for engineers to determine the quality of the pavement they are assesing to develop a redesign plan. The PCI is specified in different manuals for the pavement type being reocnstructed, and can also be a value that engineers come up with for the specific project at hand.

Current data of the air station was used from assesments taken from contractor companies, as well as field data collected on the site visit to comple an assesment of the conditions at the air statoin currently. The areas that were poor were most often in need of a full reconstruction while the fair areas often times just required a rehabilitation of them.

GIS software has also been utilized to look at the airstation area as a whole to visualize the PCI scale on a map rather than just a numerical scale in additoin to watershed rehabilitation options.

Finally once all of the areas are analyzed and recommendations have been made as to what the final design will be the team will use PAVER to develop scenarios for maintenance and rehabilitation based on budget and condition requirements [1].

For the pavement areas of responsibility, each section of pavement was analyzed for specific cracking, and determined through the United Facilities Criteria (UFC), Federal Aviations Administration, and Florida Department of Transportation, the appropriate actions as a result of the issues. First, the taxiway, which is HMA, has medium severity rutting, with ½ inch to 1 inch of deformation. This is caused by lateral movement due to traffic loads. There is no other evidence of failures. Therefore, the resulting recommendation is a mill and overlay. Rejuvenators and slurry seal were looked at as option to help with joint seal damage, but in accordance with the UFC manual, these are not permitted on military airfields. The next areas considered were the asphalt portions next to the taxiway. Some of these areas had no significant damage. The recommendations are to keep them as is, and possibly a fog seal, to keep weathering limited. Two asphalt sections adjacent to the taxiway though, had alligator and longitudinal cracking, as well as edge erosion, patching, joint reflection cracks, shoving, and weathering. This results in a recommendation of complete reconstruction with sub grade compaction to prevent this from happening in the future.

With the Portland Cement Concrete sections, there was also a variety in the conditions of this concrete. For some sections, with only weathering the options considered include concrete overlay options. A rigid or fully bonded overlay would be important to fix surface deficiencies that exist. The minimum thickness of these is one inch which would be easily adjusted with the rest of the construction. The back area of the PCC though, consists of an extensive amount of damage including but not limited to; longitudinal cracking, corner break, weathering, joint seal damage, corner spalling, and shattered slab. From this analysis the recommendations include; rotary-random saw and seal with random crack saw, which is a recommended repair in the FAA Advisory circle for longitudinal cracking, full depth repair with #5 rebar, and complete reconstruction of entire slab.

To design the pavement of Air Station Clearwater, the environmental conditions also needed to be taken into consideration. With this site being an air station, there are various environmental regulations that are required to be met. One environmental condition that was accounted for was the heavy amount of precipitation that occurs in the state of Florida. Various designs can positively or negatively affect the runoff from a large rain event, and with climate change becoming more present; more intense storms are becoming more prevalent. Because of the intensity of the storms and the elevation of the land there has been a large accumulation of water in various areas of Air Station Clearwater. The area of most concern is near the apron for the search and rescue ready C-130. This area has long lasting puddles that have stained the concrete and provided an unsafe environment for pilots.

In order to combat the runoff issues occurring at Air Station Clearwater, the storm water system is being re-evaluated as well as the elevation throughout the C-130 taxiway and aprons. Most recently, a swale system was implemented in 2012 for Air Station Clearwater. In the design, the implemented sewer system is not going to be re-done because the system is considered in good condition and it has been placed deep enough to not be conducive to redesign while reconstructing the pavement. The elevation however is going to be reconsidered; attempting to create a steady flow into the storm system present to avoid any lasting rain water.

One environmental factor that is considering being done is to take out the grass areas in between the aprons in order to allow a larger area to turn for the C-130s. With eliminating this aspect, the runoff in the pipes will increase because the surface will be asphalt which is not as pervious as grass. One of the aspects that will be accounted for is the amount of water that may be displaced into the swale system. The swale system will also be evaluated on if there is enough room to hold the excess runoff. To combat this problem, pervious concrete was taken into consideration. Pervious concrete is not recommended for use in either the UFC or FAA, and therefore can't be used in this project. These restrictions exist as a result of the heavy loading that exists at an airport as compared to a normal road or parking lot, and pervious pavement may not be able to withstand these heavier loads.

Besides removing the grass areas, the other types of pavements will remain as they have been as far as the asphalt and concrete areas. Because concrete can maintain heavy loading in a warm environment, the areas where the C-130s will be parked are to remain concrete. The other areas will remain asphalt due to financial and environmental considerations.

While both doctrines, UFC and FAA are to be met, there are certain repair methods that are widely used on facilities that cannot be used under the current alignment. Some of these repair methods include a slurry seal on weathered pavements to prevent further erosion. Slurry seal is specifically prohibited at airports under the UFC standards. Other suggestions on intermediate repairs that will be utilized are fog sealants and overlay methods. These repair methods satisfy both doctrines but may substantially hinder due to decrease in friction.

Unfortunately for the owners of the area, the soil is also contaminated due to 'venting' done by aircraft in the previous century. One possibility that was explored was to remove grass areas in between the apron and the taxiway was prevented by the high cost of removing the contaminated soil in standing with environmental codes and importing new soil. If given the opportunity the team would remove these areas and replace the grass areas with pavement for the ease of access to the aircraft while navigating the apron and taxiway.

Conclusions

The pavement for the C-130 taxiway and aprons at Air Station Clearwater is in desperate need for repair. Without the necessary repairs, the station could be unable to perform the specific missions required for the Coast Guard. Therefore, the proposed plan for this project is to produce an effective and lasting pavement design while maintaining traffic control and enabling the Air Station to be mission ready. In order to do this, the taxiway will need to be milled and overlaid. Some asphalt (the 301 and 302 areas) will need to be reconstructed as well as some portions of concrete, as repair will not be enough to fulfill the requirements for these areas. Efforts will be made to ensure that the elevation across the airport is evenly distributed, and will weigh multiple options for reconstruction and mill and overlay in order to take all considerations into account including; cost, ease of construction, safety, and water runoff. These solutions will be environmentally sufficient while taking into account the cost of the project and the finances of the Coast Guard. In addition, a maintenance plan has been developed using PAVER in order to prevent future failures in the pavement from happening. This project is projected to be financially possible for the Coast Guard to utilize, enabling (with the maintenance program) the ability to keep the price manageable for flight operations to continue in the future.

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