

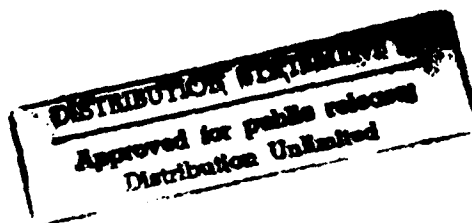
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PLANNING AND MANAGEMENT OF
AIRCRAFT PAVEMENT CONSTRUCTION

BY
TIMOTHY SMITH

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A REPORT PRESENTED TO THE GRADUATE COMMITTEE
OF THE DEPARTMENT OF CIVIL ENGINEERING IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF ENGINEERING

UNIVERSITY OF FLORIDA
SUMMER 1993

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TABLE OF CONTENTS

INTRODUCTION -----	1
PART I - MANAGEMENT AND PLANNING CONCEPTS	
CHAPTER 1 ----- MANAGEMENT AND PLANNING FROM THE OWNERS PERSPECTIVE	5
CHAPTER 2 ----- MANAGEMENT AND PLANNING FROM THE DESIGNERS PERSPECTIVE	15
CHAPTER 3 ----- MANAGEMENT AND PLANNING FROM THE CONTRACTORS PERSPECTIVE	20
CHAPTER 4 ----- JOINT GOALS OF THE OWNER, DESIGNER & CONTRACTOR	27
PART II - CONSTRUCTION CONSTRAINTS & WAYS CONTRACTORS OVERCOME THEM	
CHAPTER 5 ----- COORDINATION OF THE PROJECT SITE WORK BY THE OWNER	30
CHAPTER 6 ----- CONTRACTORS RESOURCES	38
CHAPTER 7 ----- ROLLER COMPACTED CONCRETE	40
CHAPTER 8 ----- DOWEL BAR INSERTERS	42
CHAPTER 9 ----- NEW CONCRETE CEMENT MATERIALS	45

CHAPTER 10 -----	47
PORTLAND CEMENT CONCRETE ADMIXTURES	
CHAPTER 11 -----	49
ASPHALTIC CONCRETE ADDITIVES	
CHAPTER 12 -----	55
MOBILE HOTMIX HOPPER	
CHAPTER 13 -----	57
LASER GUIDED PAVERS	
CHAPTER 14 -----	60
COMPUTER AUTOMATION	
PART III - FUTURE OF AIRCRAFT PAVEMENT CONSTRUCTION	
-----	64
BIBLIOGRAPHY -----	69

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INTRODUCTION

American travel habits have changed since the airline industry was deregulated 14 years ago. We now use air transportation almost as commonly as we do our cars. This growth has resulted in overcrowded airports and their infrastructure. More capacity is needed now but many oppose growth of airports in their "back yards."

Many believe that airport construction today is like the highway program of the 1950's. (1) Expansion of the nations airport network may mean tens of billions of dollars in construction over the next decade.

Runways, aircraft aprons and taxiways are the heart of an airport. Other supporting structures including terminals and automobile access facilities are there to support the aircraft operation pavements. (2) Just as durability and performance are essential for smooth and safe travel on highways, so are effective long lasting runways vital to an airport's success.

Any time repair or construction evolutions are taking place in and around runways there is a great chance for impacts to airport operations. Because of this construction in these areas must be carefully contemplated, planned and executed. This paper will examine management techniques used to carry out construction work in and around these aircraft support pavements and review many of the innovations that contractors and others are using to improve quality and reduce impacts to airport operations.

Just as with any heavy construction evolution, extensive planning and organization must be carried out before any equipment can be brought on site. There are some notable differences between aircraft pavement construction and other heavy construction evolutions. First, significant and definable impacts to operations in not opening a runway for morning aircraft arrivals and departures can be identified in a much more quantifiable way than other types of construction. Secondly, the work often must take place in and around operating aircraft. Sometime low flying aircraft are directly over the construction operations. Extreme safety precautions and coordination with airport operations must take place.

The remainder of this paper is divided into three parts. The first deals with the most important aspects of aircraft pavement construction, management and planning concepts. This section looks at the process from the owner, contractor and design professionals perspectives. Organization concepts, project scheduling and contract types are discussed. The second section looks at technical developments that are in use to improve productivity and minimize operational impact. Materials, equipment and work crew organization along with computerization is examined. The last section is a conclusion that also looks at the future of airport construction.

PART 1

MANAGEMENT AND PLANNING CONCEPTS

CHAPTER 1

MANAGEMENT AND PLANNING FROM THE OWNERS PERSPECTIVE

The owner is the one who has the most to lose if aircraft pavement construction work is not accomplished properly. The owner is not just the physical plant manager or construction manager. He or she is the entity that runs all aspects of the runway operations including coordinating with the airlines, controlling aircraft traffic terminal operations, operations of passenger service functions and all other functions associated with running an airport. Success for the owner goes beyond quality workmanship and timely completion. Although these are both important, the airport management's paramount concern is with maintaining aircraft operations and minimizing the impact and disruption during the repairs or construction.

With this primary concern in mind, the owner's physical plant organization will formulate a strategy for design, procurement and management of the pavement work. The airport authorities must look at their organizational size

and their in house engineering capabilities and the amount and complexity of the work to determine the mix of how much of the planning, engineering and craft work can be done within the organization and how much will be done by outsiders.

FIXED PRICE CONTRACTS

The "traditional" approach of hiring an engineering firm to design the project as a Fixed Price contract then advertizing for a contractor has been the most common approach in the past and will likely continue to be the preferred strategy in the future. This procurement systems has many benefits. Because it has been used for so long, all parties that are involved understand the process and how they fit into the system. In theory the bidding process is based on economic supply and demand. The contract is awarded to the lowest bid contractor. Because cost is the only criteria for award, some of airport managements other goals including minimizing disruption of aircraft operations may not be addressed adequately. Other options are now available to the airport manager that may allow greater flexibility and capabilities to meet his or her objectives.

MULTIPLE PARAMETER CONTRACTS

One such procurement method is a selection process where multiple parameters are use to select the contractor.

(3) Primarily cost, time and quality are used to as criterion to assess each bid. Other criteria can be added such a as safety, security and operational impact. The contract package must state the parameters that will be used, relative weights that each parameter has and the system used to measure them.

As was indicated earlier, the owners overriding consideration during construction work is to minimize impact on aircraft operations. By including this criteria in the bid analysis less impact may be achievable. Different management organizations or new construction techniques are being used by some construction contractors that have will decrease operational impact and contract cost.

For example, using the conventional system, a fixed price contract is written where the contractor is directed work on taxiway A first followed by runway 23R then taxiway B. This work could involved different work elements where phasing it like this will cost prospective contractors more than other phasing concepts. The airport operator felt he or she had to do the work this way to meet operational

requirements. If on the other hand the operator clearly spelled out the operational requirements such as work on runway 23R must only take place from 9:00 pm till 5:00 am and the contractor must maintain a 100 ft clearance from the end of the runway during other times, and other necessary criteria, the contractor may be able to creatively look at the limiting requirements, his equipment and manpower constraints and develop a more economical phasing structure.

By weighing his plan along with the other parameters, there may be a lower contract cost with all of the operational constraints being met. The major hazard here is in ensuring that all of the operational considerations are clearly spelled out in the contract package. Failure to do this will result significant additional modifications to the contract and claims by the contractor for additional time and money.

UNIT PRICE CONTRACTS

There are some circumstances where the more common lump-sum type of contract will not adequately function as the best avenue for construction. Often this is because the exact volume of the work can not be determined. This is very common in pavement projects. The owner may not have

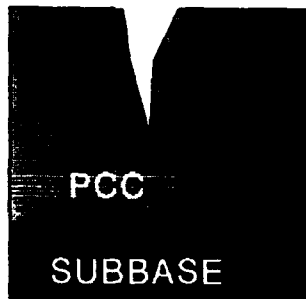
the equipment or manpower resources to perform repair and/or maintenance work or he or she may be unsure of the level of subsurface repairs that will be required when he or she initiates the work. In these cases, unit-price contracts may be well suited to this type of work.

Spot repairs to pavements can often be categorized into specifically types of repairs and be easily defined in a unit-price contract package. As an illustration, minor cracks 1/4 in. to 1 in can be defined as Type I cracks while ones greater than 1 in across can be defined as Type II. The scope of the work that the contractor can be clearly defined in the plans and specifications. Figure (1) shows examples of this.

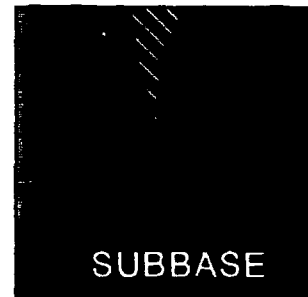
Unit-price contracts offer many of the advantages of conventional competitive bidding yet allows reasonable variation in the quantities of work items with less chance of formal change orders. The contract package must completely describe all types of repairs and provide to contractor an estimated quantity of each type of repair with a range of fluctuations of the estimate so he or she can

TYPE I REPAIRS

Existing

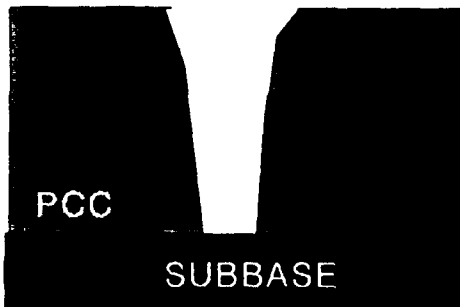


Pavement
Repairs



TYPE II REPAIRS

Existing



Pavement
Repairs



PORTLAND CEMENT CONCRETE



JOINT SEALING FILLER COMPOUND

Public Works "Busy Airport Rehabilitates Runway to increase service life."

understand the scope and complexity of the job. It is common for contracts to be a mixture of fixed-price and unit price work in the same contract. A contract could call for a fixed price overlay with joint and crack repairs being unit-priced.

DESIGN-BUILD CONTRACTS

Many types of construction lend themselves to combining the design and construction elements into one contract. This type of procurement has may have potential benefits over the conventional system including clearer transfer of liability, not-to-exceed pricing, construction cost savings and overall time savings. The few studies have been conducted on this type of procurement have provided conflicting results. One related study of Florida Department of Transportation design built pilot program found that sizable time savings were possible while cost variance was less clear to determine.(4) This study was not directed at aircraft pavement construction. Despite this there maybe some correlation between the two types of construction. The time savings may be worth the risks in some aircraft pavement construction cases. If there are

indications of imminent failure of critical pavement, then using this method may be prudent. In most less time critical cases using normal methods would be the most prudent.

This method has its opponents who point to several areas that of concern. First is that contractors do not have the organization to provide the full design services needed to bid on this type of work. Likewise engineering firms do not have the trade knowledge to construct a project. This means that some type of joint venture arrangement is often required. Also bidding this work may be more expensive than normal contract solicitations. Some avenue for recovery of some part of the design costs should be found to ensure that smaller less experienced firms are not "priced out" of completion.

COST-PLUS CONTRACTS

There are several other contract types that are could be used for aircraft pavements in certain circumstances but common use is not the case nor will it likely be in the future.

Cost-plus contracts pay the contractor for his costs plus some calculation for additional funds based on a fixed fee, percentage of work done or some other formula. This type of contract is usually preferred if unusual problems are expected to be encountered, the owner desires to start work prior to design completion, or where the contract involves new technology or in a remote location. Most aircraft pavement work does not fall into any of these categories so using cost-plus contracts is not recommended.

PROFESSIONAL CONSTRUCTION MANAGEMENT

The concept of Construction Management is new and may give the owner another approach to correcting his or her pavement problems. Professional Construction Management (CM) treats project planning, design and construction as integrated tasks. The use of CM gives the owner several advantages over other systems. First, it supplies construction expertise to all phases of construction. The construction manager provides an independent evaluation of cost, schedules, performance, and changes that keep the owner informed, allowing for timely decisions. Secondly, it allows for phased construction thereby reducing the overall project duration. This maybe

critical for aircraft pavement projects where large scale construction efforts are planned with the need for concurrent heavy air operations. Finally, this procedure tends to replace the adversarial relationships associated with the traditional process, using a team approach.

CHAPTER 2

MANAGEMENT AND PLANNING FROM THE DESIGNERS PROSPECTIVE

The design professionals component in the process is to ensure that a quality design is developed that will minimize the impact to airport operations. In addition to the normal constructions specifications, he or she must clearly incorporate the operational constraints on construction in the contract package. Work involving aircraft pavements are very often space and time constrained. Because of this there are many specialized items that the designer must address in his specifications. (5)

1. For the operational considerations, the owner will want the project to proceed in a speedy manor. Often airport operations will required multiple construction phases, limited working hours. Special routing of aircraft considering airline schedules, lead time for clearance of runway, taxiway, or apron, by construction

equipment, notification of schedule changes, and other constraints will have to be dealt with.

2. Access to the construction site by the contractor personnel, for material deliveries, and equipment movements must be controlled. Crossing active operations areas may be needed and require special precautions. Depending on the location of the construction site, and its proximity to operating runways, taxiways and aprons, this can be much more serious than other types of construction.
3. Deposal of waste products and clean up requirements to eliminate Foreign Object Damage (FOD) from entering operational areas.
4. Establish minimum distance restrictions for construction vehicles, workers and material in relation to runway, taxiways and navigational aids remaining in operations during construction.
5. Temporary aircraft operational changes and their effect on the construction project including threshold displacement, temporary markings and lighting should be included. Maintenance responsibilities for these should be specified.

6. The parking of construction equipment and vehicles when not engaged in construction, during nonworking times should be specified.
7. The allowable location contractors stockpiles, construction office and plant should be identified. The requirements for marking and lighting the construction area should also be indicated.
8. Requirements for standby equipment for critical equipment

All of these restrictions significantly increase the contractors costs. Failure to included them will either result in unacceptable operational impact and/or contractor claims for additional funds.

The design professionals participation in the process does not end when he or she has completed the plans and specifications and provides them to the owner. He or she is the most knowledgeable one about the design intent and technical requirements. By responding in a timely manor to owner and contractor requests for information and clarification during construction, he or she will be able to keep work progress on schedule.

Site visits are just as critical in aircraft pavement construction as in other heavy construction projects. These visits allow the engineer to see that the work is proceeding as planned and in accordance with his or her specifications. It also educates him on the field's technical and operational problems. In addition to contractual and legal obligations after construction starts the should have some pride of ownership in his or her design.

Normally the designer will be responsible for review of contractor submittal to ensure they comply with the requirements of the contract. Timely review is important to ensure the project remains on schedule.

Due to the nature of the work and coordination with airport operations, full time site engineering is required. For many reasons this function may or may not be performed by the designer. The governmental or other organization that controls the airport may have an excellent construction services organization. Another engineering firm may be hired because some fear that a design error will be hushed up by the design agent. Communication with the contractor and the airport operational authorities is critical to the success of the project no mater who is chosen to be responsible for this phase of engineering. (5)

The construction industry is one of the most hazardous industry in the country. Designers have traditionally distanced themselves from responsibility for site safety. More governmental agencies and other organizations are requiring that design firms be responsible for the construction contractors job safety. Future court cases may force engineering firms to re-look at there roles.

As was indicated previously, aircraft pavement construction often has significant time and space constraints placed on it. Because of this, there is a much higher chance of accidents and injury than many other types of construction. The fact that the engineers site personnel have no direct authority over the contractors employees, many legal authorities believe that by having the design firm in charge of safety oversight, safety rules will be better enforced. (5)

CHAPTER 3

MANAGEMENT AND PLANNING FROM THE CONTRACTORS PERSPECTIVE

Both the owner and his design agent have responsibilities to develop a complete design package. It is the contractors responsibility to carry out the work within the constraints and in an economical manor to ensure he makes a profit. His or her planning and workmanship is the most complex and challenging portion of the total process. By wisely controlling material, equipment and manpower costs the contractor will be able to successfully complete the project.

In a recent project to construct a new runway for Atlanta's Hartsfield Airport, a joint venture by C.W. Mathews and Bellenger Corp completed the project, on time with minimal operational impacts. The project superintendent saw that planning was the key to success. He indicated that, "Planning our paving work...to keep everyone's crews on schedule has been the key to success..."

It's hard to loss money when you keep the project on schedule - that is the real payoff for good project planning." (6)

ORGANIZATIONAL STRUCTURE

Each construction company has it's own manner of setting up and organizational structure to perform the site work. This challenge is faced with each new contract. Variations in goals, situations, and aircraft operational requirements dictate unique structures.

Several basic principals should be reviewed to determine the best structure. To be effective organizations should: (7)

1. Establish clear responsibilities for external interfaces with owner, design professionals, material suppliers, and aircraft operations personnel.
2. Provide a single point of responsibility at the lowest practical level.
3. Integrate craft, engineering, planning and materials resources at the lowest practical level.
4. Establish and enforce craft discipline priorities consistent with the construction phase of the project.

5. Limit managerial spans of control.
6. Assure clear and effective communications and reporting relationships.
7. Assure most effective utilization of management, support and craft resources.

Circumstances may dictate additions to these but this represents many of the criteria that should be addressed for nearly all organizations. Trade-offs among the criteria some times must be made to form the best possible organization.

There are a huge number of possible organizational structures. Construction work involving aircraft pavement is specialized, but scope variations, contractor resources and the mix of repairs vs. new construction make delineation of the "best" structure impossible. The contractor must carefully look at all of his strength, weaknesses and resources to develop an organization that will best allow him or her to manage the project.

EQUIPMENT MANAGEMENT

Just as in most pavement related construction the work, aircraft pavement construction is heavy equipment dependent. Much of this equipment is specialized for specific pavement

operations can be utilized for little else. (8) In addition its high cost requires procurement and operations to be accomplished with great care. Too often contractors want to buy newer and bigger equipment. The rational for purchasing new is often either to replace the old or for expansion. While both are sound reasons, careful decision making must be done because the contractor will be committing considerable financial resources without guaranties of future work. He or she must weigh the marginal benefits of greater productivity and asses the reduction in maintenance required for the new equipment. Since very little else but paving can be done with this equipment, careful assessment of future market must be accomplished. Is the amount of airport pavement construction on the up swing due to the increase in passenger demand or will economic realities force governing bodies to defer further work? This question must be addressed to fully asses the profitability of new equipment purchases. To accurately bid a contract, one must know how much unit cost of equipment will be. All replacement, maintenance and other costs should be included.

PROJECT PLANNING

Once a team has been formed, in depth project planning should be undertaken. The project manager, superintendent and other senior players need to develop a construction plan that address all constraints and will provide an end product at the lowest possible cost to ensure a reasonable profit.

(9) This planning should be review site plans, specifications, operational constraints, safety concerns, existing pavement condition surveys (if available), equipment availability, manpower requirements, native materials, and methods of construction to determine the best method of accomplishment. (10) Figure (2) diagrams the process that contractors must undergo to develop their project plan.

The amount of planning should be proportional to the complexity and cost of the project. Proper planning is critical in all cases though. Making the right decisions on resource use, construction methods and working around operational constraints will be much easier at this point than later. The cost of making changes in the plan will increase over time.

CONTRACTOR PROJECT PLANNING

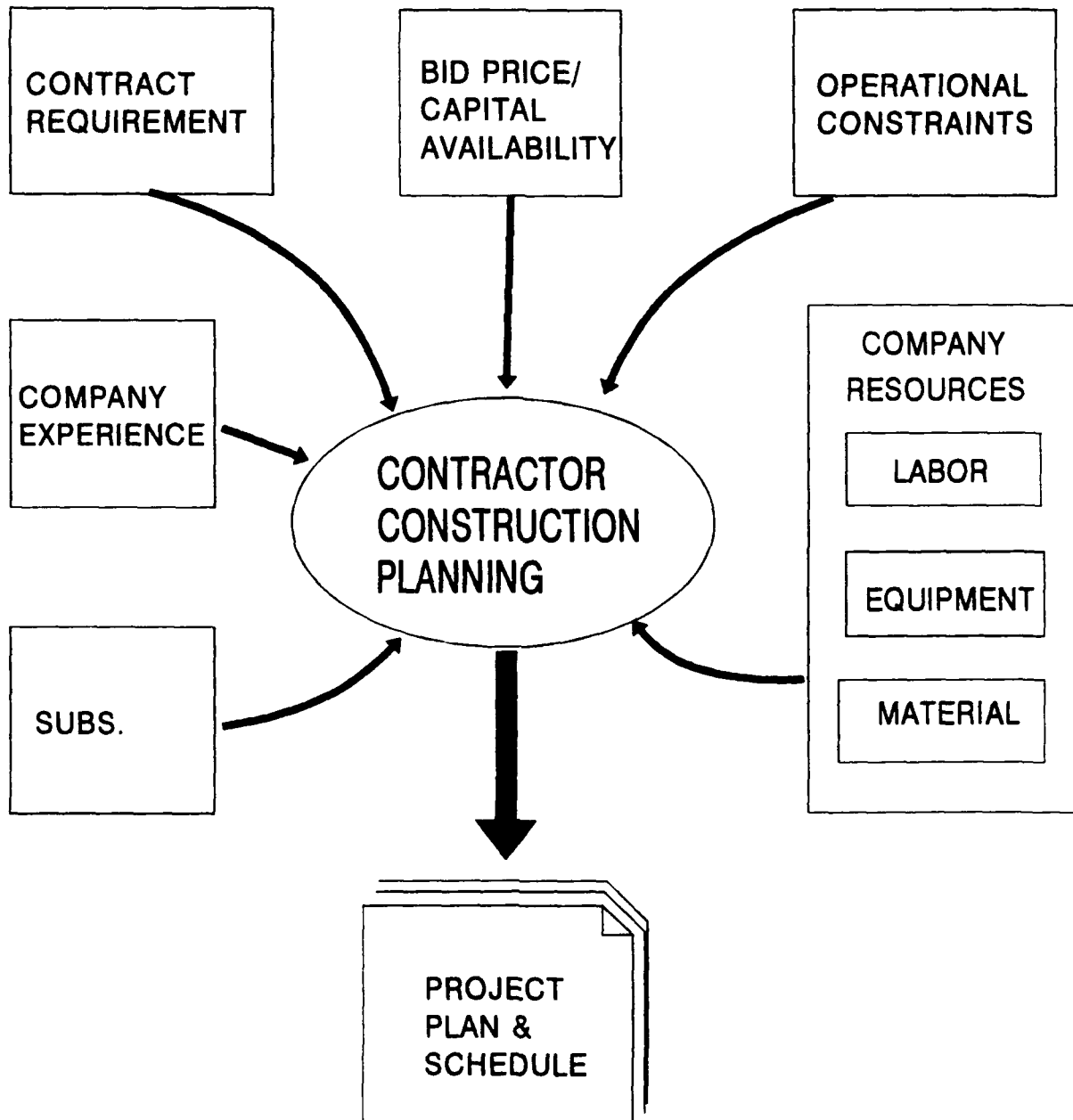


Figure 2

The second part of this paper will address how contractors are using the planning process to examine their human and equipment assets to meet the operational constraints of aircraft pavement construction projects and make a profit.

CHAPTER 4

JOINT GOALS OF THE OWNER, DESIGNER & CONTRACTOR

The success of an aircraft pavement construction project is heavily dependant on the owner, the designer and the contractor working and communicating closely with each other. All of the parties involved with aircraft pavement construction have their own specific goals for the project, but many common goals can be found. Some of the common goals for each major player that are found in most aircraft pavement projects are shown in table (1). (11)

COMMON GOALS FOR AIRCRAFT CONSTRUCTION

OWNER	CONTRACTOR	DESIGNER
* QUALITY WORK	* QUALITY PRODUCT	* QUALITY DESIGN
* MINIMAL OPS IMPACT	* REASONABLE PROFIT	* ACCURATE DEPICTION OF OWNERS REQ'R
* NO DISPUTES	* NO LITIGATION	* REASONABLE PROFIT
* ON TIME WORK	* ON SCHEDULE	* NO DISPUTES
* NO REWORK	* NO REWORK	* NO ACCIDENTS
* WITHIN BUDGET	* NO ACCIDENTS	
* NO ACCIDENTS		

Woodrich, "Partnering:providing Effective Project Control"
Table (1)

The owner wants to minimize operational impacts while having a quality product within budget that will last the design life with minimal future maintenance. The designer wants to provide the owner with a design that will meet his or her quality needs, budget and operational constraints. The contractor has pride in his work and wants to meet all contract requirements and make a reasonable profit on the job.

Its a common misconception among owners and design professionals that contractors want disputes to increase profits. This is not the case, none of the parties want disputes. Disputes cost the contractor time and money to settle and takes away form there ability to manage their workload.

This need for cooperation between all parties associated with this type of work makes partnering aircraft pavement construction ideal. Partnering can be best summed up as getting "back to the old way of doing business with a handshake and taking responsibility for what you do." Partnering formalizes this concept and fosters good relations between all parties. It allows all parties to see and understand the other's goals and needs. Because of the inherent need to work together to minimize operational impacts, their is a great likelihood that partnering will be used more often in the future for aircraft pavement construction.

PART II

**CONSTRUCTION CONSTRAINTS
& WAYS CONTRACTORS OVERCOME THEM**

CHAPTER 5

COORDINATION OF THE PROJECT SITE WORK BY THE OWNER

Coordination of all of the people involved with the process is of paramount concern. If the owner does not adequately coordinate the organization's involvement with the project, then significant operational impacts will likely occur along with adversarial relations with the contractor. Once the contractor has been determined and award notifications have been given, the owners should first hold a pre construction conference with all parties concerned with the project to introduce each other. (12) This meeting, among all parties affected by the construction, should assist in a better understanding of potential problems and possible solutions. Just as in any other preconstruction conference the attendees include the owners construction representative, the contractor and any subcontractors, the design engineer, and representatives from various affected operations organizations. These operations organization encompass all airport management, airlines, fixed base operators, Airline Pilots Association, and FAA representatives consisting of Air Traffic Control personnel and other effected parties. (12)

The items discussed include many that are common to all construction projects such as quality control, material testing record keeping, labor law considerations and environmental controls. The additional considerations entailed with aircraft pavement construction mean that special emphasis should be given to several areas. This includes the need for continuing vigilance to identify and overcome hazards brought on by the space and time constrained work in and around operational aircraft. Also of concern is the need to fully return the area to operational capability at the end of each phase. This concerns is especially important when the work involves working nights and returning the area to aircraft operations the next day.

Much of the detailed construction functions going on during aircraft pavement construction is the same as what goes on during many other types of construction. Asphalt paving operations for highways has many of the same construction techniques as paving aircraft pavements. Paving machine, rolling techniques and other aspects are similar. A major the difference lies not so much in the construction process but the location and special precautions that must take place during construction.

In only the most rare circumstances are construction efforts undertaken unencumbered with a total closure of the airport. When this occurs the construction can go on with

less concern for the direct aircraft safety and operational impacts that they will have on the airport. Construction on entirely new airports is an illustration of this. While Denver's new airport is being constructed, the contractor does not have to concern himself with common problems such as phasing operations to complete work and remove equipment by the mornings flights.

Sometimes emergency or other types of repairs are necessary that will completely close an airport. If the area(s) needing repair are on the primary runway(s), or an airport with only one runway, or at a critical juncture of multiple runways, complete closure maybe necessary. Closure will reduce the close coordination that is required to ensure operational safety. It is very likely that the time constraints imposed on the contractor will be very stringent to ensure that the airport operations resume as soon as practical. Because of this compressed time of performing work, construction safety becomes a significant concern.

TIME CONSTRAINED CONSTRUCTION

A more common situation involves short duration partial to full closure of air operations while construction efforts are undertaken. This Time Constrained Construction often is undertaken at night or other low aircraft volume times to reduce operational impacts. Often the contract will call for the contractor to start work in the late

evening and must have the work site capable of supporting operations by early the next morning. (13)

Time constraints require close coordination between the contractor and the owner's construction representative. The owner's representative should be familiar with the air operations that normally occur at the airport and also how operations will be altered during the construction evolution. (14)

Prior to authorizing the contractor to start the evenings work (or other specific time period), the owners construction representative must first check weather reports to determine if it is prudent to start work. In most pavement construction evolutions weather is an important aspect to be considered to ensure a quality product. In this case the owner's representative is not checking to determine if conditions are adequate for proper construction. He or she needs to look at the weather conditions to see how they will effect operations of the airport. Rain, wind changes or fog creeping in during the night may necessitate changes in runway use and limit the availability of the work are during that evening.

During the planning phases the owner's representative will have discussed the proposed time constraints with the operational personnel at the airport including Air Traffic control personnel ,the airlines and FAA. The nature of flight operations is such that changes in operations are

likely for each individual evening. Because of this the representative should again check with the operations personnel to ensure that all arriving and departing flights would be completed prior to the contractors mobilization and start of work. Specific sketches of the evenings work should be provided to ensure they understand where the contractor will be working.

The contractor should be informed of any potential changes in the airport operations. Delays in start or required completion times or suspension of work are possible and should be clearly understood by all. Some of these operational changes include:

1. Arrival of aircraft after start of operations.
2. Late departure of aircraft due to late arrival.
3. Weather conditions requiring changes in the operations of runways or taxiways if the airport will not be closing during operations.

At the start of the evenings work, both the owner's representative and the contractor should agree on the scope of the time periods work. The amount of work should be controlled and monitored to prevent and "over ambitious" work plan. The consequences of planning to much work are significant because of the impact on planned aircraft arrivals. This is especially critical for projects involving large scale repairs and replacements.

Safety and operational constraining information should be given to the contractor personnel before the start of the project and during it as necessary.

At the completion of the evenings work and before opening the pavement for aircraft operations, the owners representative, operations officials and contractor superintendent should jointly inspect the area. This should include careful checking of transition between new and existing pavement, FOD removal, and equipment removal for operations areas.

SPACE CONSTRAINED CONSTRUCTION

Another common scenario of work is that only limited portions of a airport will be closed to aircraft while construction progresses. Also construction of expansion runways, taxiways and aprons at existing airports can be space constrained. Aircraft operations will continue in areas outside the construction site. Tight control is maintained on limiting construction activities to the runway(s), taxiway(s) and/or apron(s). Depending on the geometrics of the aircraft support pavements, aircraft operations may come in close proximity to construction work. Low level overflights of aircraft are common situations that require consideration.

Access to the site should be carefully considered. Manpower, equipment and material must be brought to the site. In order to access many mid field work areas, the contractor may have to cross operational areas or otherwise impact airport operations. These transit routes must be carefully arranged with the idea of elimination, as much as feasible, the crossing operational pavements. If crossing is needed, all vehicles should be equipped with two-way radios and personnel should be briefed on required communications procedures prior to crossing.

The actual work site should be carefully delineated to ensure that all construction people and equipment stay within it. No equipment should be allowed to leave the area without the owner's representatives consent. Special care should be taken to ensure that foreign object damage (FOD) material is cleaned up regularly and is not allowed outside the limits of the project works site.

Just as is the case in time constrained work, safety and operational constraints should be given to the contractor personnel before the start of the project and during it as necessary.

During the planning phase the owner's representative will have discussed the work site space constraints with the operational personnel at the airport including Air Traffic control personnel ,the airlines and the Federal Aviation Administration. The nature of flight operations is such

that changes in operations are likely and these changes could effect the location of the work. Because of this the representative should regularly check with the operations personnel to ensure that work location does not effect aircraft operations. Specific sketch of the work should be provided to operations personnel and updated periodically. The contractor should be informed of any potential changes in the airport operations. Delays in availability of sites or suspension of work are possible and should be clearly understood by all. (14)

CHAPTER 6

CONTRACTORS RESOURCES

Just as in the case of planning and managing, the contractor has the most challenging and risking part to play in aircraft pavement construction. In order to compete the project within the contract requirements and make a reasonable profit the contractor will have to ensure his or her competitiveness with others who are vying for the contract.

In addition to ensuring a competitive organizational structure and precise control over the project various improvements to contractors equipment and material are being developed to improve paving speed and quality. Many of the improvements do not result in a quantum leap forward in speed ease of use or quality. Also they do not radically change the technique that is used for pavement whether it is portland cement concrete or asphaltic concrete. They do however represent significant enhancements in the construction process. (15) (16) Each improvement in itself refines the means and methods to make the contractor more competitive. This paper can not describe all of the innovations that institutions, manufactures and contractors

are developing. It will describe many of the ones that contractors are using now to improve there competitive edge and win contracts.

CHAPTER 7

ROLLER COMPACTED CONCRETE

Many people have realized long ago that if existing material could be reused, as base material the cost of construction new concrete pavement could be reduced. Very often this resource is not reused because of oversight or concern that the contractor will not be able to adequately compact it or otherwise does not have the technical knowledge to reuse it. Several companies have refined Roller Compacted Concrete (RCC) to reduce costs of construction.

Madden Contracting & Material Co. Inc, was subcontracted by the prime, Hyman Construction Company to do the grading, base and paving for a new taxiway and apron area at Andrews Airforce Base. (17) The contract plans called for a 14 inch concrete pavement to be constructed over a new 8 inch granular base and 4 inch drainage course. As value engineering proposal, the subcontractor suggested a change to reduce the cost with no decrease in durability or strength. Rather than disposing of the existing pavement in a designated off site location, and importing virgin aggregate for the granular base, the subcontractor proposed

replacing the granular base with a 6 to 7 inch Roller Compacted Concrete (RCC) course to be constructed with the aggregate made from the old concrete pavement.

The subcontractor found that they could set up their own portable crushing plant and recycle the old concrete economically. Using this crushed material along with virgin fill from the area that was originally designated as the disposal site, nearly all there base course requirements were met. The new mix design used 60 percent recycled aggregate, (1 1/2 in minus), 33 percent virgin aggregate, 7 percent cement and water to bring the mixture to the optimum moisture content.

The machine that was used to spread the recycled material was an asphalt paver adapted for RCC work. This machine shapes and extrudes the mix under its rear screed where it is compacted further by two oscillating tamping bars. Following this, vibratory drum rollers made passes to complete the compaction.

Under the terms of the Value Engineering clause of the contract, the savings of \$104,000 was divided between the federal government and Maddden. The change did not lengthen the contract completion time and provided a equally durable end product.

CHAPTER 8

DOWEL BAR INSERTERS

Several companies have developed dowel bar inserters on there paver machines to speed the process and provide better quality. Traditionally dowels have been manually placed using baskets at the joint location. During a recent project constructing a new runway at Cincinnati International Airport, the prime contractor, The Harper Co. incorporated this improvement on their paver's to pave at a rate of 7000 cubic yards per day with up to three paving trains. (18) The contract requirements called for closely spaced joints with 47 dowels phased per joint. This resulted in 2.8 bars being placed per running foot of slab. The Dowel Bar Inserters used for expansion joints were loaded with dowels on each side of the paver. From there the dowels dropped into slots in preparation for each joint. The paver operator pushes a button to release the dowels when the paver reaches the proper location. When the dowels ar dropped, four vibrating fingers push them onto the concrete. The Dowel Bar Inserter remains stationary as the paver continues to move forward. After the fingers have placed the dowels in there proper place, the Dowel Bar

Inserters return to its original position and is ready to place the next set of dowels. A correcting beam smooths out the imperfections that are left from placing the dowel. A pair of Dowel Bar Inserters are located in the rear of the paver with one on each side. The bars are injected into the sides of the slab at the halfway point every 18 in on center with a hydraulic cylinder. This process not only saved time but it also eliminated microfracturing which could result from drilling to insert the dowels later.

Another contractor Shelly and Sands Inc. has devised an efficient system for installing dowels in patching existing concrete pavement. (19) The company mounted an epoxy dispensing machine and multiple bit hydraulic drill on a backhoe. The backhoe's hydraulic systems provides power for both the dispenser and drill.

Using conventional methods hand drills are used to drill holes; epoxy is mixed in buckets and allied to the dowel and the dowel is set in the hole.

In this improved method, workers use the hydraulic drill to bore a 1 1/8 inch diameter hole in the existing concrete. The epoxy dispenser feeds an precisely proportioned two-part epoxy paste through a high pressure hose and hand held dispenser gun. Employee's inject the epoxy into the hole then inset the bars. Epoxy components

stay separate until they enter the mixer portion of the gun for blending. With mixed expoy commonly having a 15 minute usable life this saves 25 to 30 percent in wasted epoxy over conventional methods.

CHAPTER 9

NEW CONCRETE CEMENT MATERIALS

Improving the equipment performance is only part of the equation of faster placement of concrete and higher quality finished product. Improvements in the concrete cement material are ongoing at a similar pace as equipment improvements.

A major concern that airport operators have is that they want to have a return to normal operations as soon as possible. Portland cement concrete takes time for an initial set to take place and for it to have cured to a useable point. Because of this many companies and organizations are looking for materials that will set faster when repairing existing concrete.

One such product Pyrament developed by Lone Star Industries Inc. Concrete made from this cement achieves its fast high strength of 2500 psi in about four hours. This is done without addition of any admixtures. Normally the concrete can accept airline traffic in six hours.

This product was recently used for repairing a 6,300 ft runway at Yeager Airport in Charleston West Virginia. (20) Using conventional materials, the main

runway would have been closed for almost a week until the concrete gained enough strength to support aircraft traffic. To minimize the operational impact of this, Pyrament was used. The last jet to use the main runway lands at 11:00 pm each night. Following the aircraft's exit from the runway work crews move equipment to the runway to remove the existing damaged concrete, clear out holes, mix and place the concrete, score the runway groves clean up and remove their equipment. All of this was done in only three hours. The last batch of concrete was placed by about 3:00 am and the first plane took off at 9:30am the next morning. The entire project was accomplished with no operational impacts and no construction related traffic delays.

Ideal Cement Co. developed a new product, Regulated Set Portland Cement which can be used to replace failed sections of concrete in a matter of hours. The preparation and placement of this product is the similar to Pyrament and not radically different from conventional Portland Cement Concrete. The concrete mixture sets within 45 minutes and reaches a compressive strength of 2500 psi in three hours and 6000 psi in two days.

Products like these have a wide applications for repair and construction of aircraft pavement. It is very likely that many more fast setting products like this will come on the market in the near future.

CHAPTER 10

PORTLAND CEMENT CONCRETE ADMIXTURES

Admixtures that decrease the curing time of Portland Cement Concrete have been used for some time. Faster repair times and less impacts to airport operations offset these materials slightly higher costs. The most common is calcium chloride. When used in small quantities it acts as an internal curing agent, assisting in the hydration process and acceleration the chemical reactions. (21) Due to its corrosive effects on steel, there is limited use for many pavement construction applications.

Many new chemicals with the same accelerating qualities are being developed for use in pavement repairs. (22) One of the best known one is Magnesium-phosphate based additives. These allow the concrete to set in as short a time as 15 minutes and be ready for traffic in a few hours. Different mixtures are often available for use in various weather conditions including hot weather formulas which contain a retarder to ease work in warmer temperatures.

These mixes have different mixing orders and mixing times than conventional concrete. To ensure a lasting repair, it is best to strictly follow the manufactures

directions. Magnesium based mixes have significantly shorter mixing times than portland cement mixtures. Mixing longer than necessary is not needed and will only reduce the amount of working time available. Because of this short time, the mixing operation should be located as close to the repair area as possible. To minimize waste one should only mix slightly more concrete than is required.

CHAPTER 11

ASPHALTIC CONCRETE MIXING ADDITIVES

Many authorities are continuing to look for ways to extend the life of asphaltic pavements at lower cost. Higher crude-oil prices, increased use of spot sources and more competition for oil derivatives mean that contractors are seeing a grater variety in asphaltic cements and their characteristics. Manufacturers are developing Polymers that could improve asphalt flexibility in low temperatures and rigidity under summer's heat. (23) When the right combination of asphalt and polymers is ascertained, often by trail and error, the polymer forms a lattice in the bitumen. The two material do not form a chemical bond but a molecular entanglement where the binder takes on some of the polymers properties.

The goal of theses additives is to extend asphalt pavements performance properties throughout the anticipated working temperatures as high as 140 degrees F to as low as -20 degrees F. Through this range, polymers are expected to remain pliable at processing temperatures and adhere the aggregate better. To protect from rutting and shoving, plastomeric polymers such as ethylene/vinylacetate

copolymer,ethylene/acrylic acid copolymers and acrylic ester copolymers are being used. These materials can raise asphalt softening temperatures by as much as 10 to 15 degrees and make the mat more ridged in hot temperatures. Prevention of cold weather cracking can be achieved buy using elasometric polymers such as natural latex, styrene/butadien rubber, styrene/butadiene block polymers and neoprene. These materials can lower the temperature at which asphalt will break from 32 degrees to -10 degrees. Copolymers seem have the best attributes of the two different molecules to give a variety of performance characteristics.

Table (2) provides some of the characteristics of some of the currently available polymers. (23)

For the time being, polymers offer in some cases to many options. Not all polymers are compatible with all mixes. In addition there is some variability in cost. Polymers add from \$1 to \$5 per ton to the cost of the mix.

Engineers who desire to specify polymers should work with many manufactures to design a system that meets their specific objective. The alternate is to buy asphalt already mixed with a polymer. The premixed products most manufactures are marketing usually differ from other polymers in that the pre mixed ones bond chemically with the asphalt. The companies engineer their mixtures according to

gradation of aggregate used and the purpose of the pavement. Mixes can be allied as slurries, overlays or even full depth sections.

CHARACTERISTICS OF POLYMER-MODIFIED ASPHALT

Modifier	Unique Performance	Deficiency
Styrene/butadiene block copolymer (SBS)	* outstanding toughness * excellent elastic recovery	* mixing/blending * melt storage stability * ductility
Styrene/butadiene latex (SBR)	* ductility	* mixing/blending * melt storage
Natural latex	* aggregate retention * good ductility	* mixing/blending * melt storage stability
Polychloroprene (Neoprene)	* toughness * elastic recovery * torsional recovery * compatibility	* ductility * lack of toughness
Polyolefin (PE, PP, EVA)	* modulus(stiffness) * aging resistance	* mixing/blending * melt storage stability * ductility

Stewart, "Polymers: Pavements Miracle Additive ?"
Table (2)

Micro-Surfacing is a versatile cold-mix paving system using polymers that was pioneered in Germany. (24) Micro-surfacing consists of as a mixture of dense-graded aggregate, asphalt emulsion, water and filler. Applications include increasing skid resistance, adding service life to

high-speed, heavy-traffic surfaces and filling wheel ruts up to 2 inches deep. This product can also create a new stable surface that better resists rutting and shoving in hot temperatures and cracking in cold temperatures. This technique was used to increase the service life of both primary runways at Naval Air Station Keflavik. It increased life to allow for design and funding of full scale overlaying that was ultimately required.

Another idea for additions to asphalt mix that promises improved stability is Fiber-Reinforcement. (25) Adding several pounds of these silk-like polyester fibers may prove to be a practical method of improving asphalt stability. Research on this is ongoing in several locations including Clemson University. While inclusion of fibers has many positive benefits, performance appraisals over time and loadings, and an analysis of the economic feasibility studies still need to be accomplished.

Clemson's research examined the effects of homogeneously dispersed polyester fibers on the tensile strength of asphaltic concrete surface courses. They also investigated the effects of differing amounts of fiber, fiber size and length. They found that:

1. The tensile strength ratios of the fiber mixtures increased 1 to 33 percent as compared to the control mixture.
2. The addition of fibers resulted in increased toughness of up to 26 percent in the dry condition and 100 percent in the wet condition.
3. The mixture with 0.5 percent 1/2 inch, 30 denier fibers provided the most improvement in toughness and higher tensile strengths
4. Inclusion of polyester fibers resulted in an increase in the optimum asphalt cement contents from 0.3 to 1.0. It also increased air void contents.

The experiments included both batch plant and drum mixer investigations. In the batch plant tests, the fibers were well dispersed throughout the mix but there were also "balls" of fibers which marred and tore the surface of the pavement. Researchers believe that the "balls" occurred because the short time the fibers were in the batch plant's mixing chamber before the asphalt was added. This likely could have been eliminated if a separate feed to input the fibers simultaneously with the aggregates was added or a storage silo would have been used.

The second experiment took place at Columbia Metropolitan Airport. More than 300 tons of polyester fiber-reinforced pavement was placed in one area while a like amount was placed in an area with similar traffic loading. Using the drum mixer, the fibers and aggregates were cascaded and blended for about 25 seconds as they traveled down a drum then were coated with asphalt. From a contractor standpoint, the only apparent problem that existed was with finishability when the 1/2 inch fibers were used. When they switched to 1/4 inch fibers there were no problems and a good finished product was achieved.

Only after more long term tests to determine how this product stands up over time will we will be able to determine if fiber reinforcement will have real potential to improve aircraft pavement placement.

CHAPTER 12

MOBILE HOTMIX HOPPER

As has been indicated earlier, speed and high production can be significant considerations in aircraft pavement construction. Contractors need to find ways to keep high production on their paver machines. One idea that some contractors are using is use of Mobile Transfer Vehicles (MTV) a intermediate storage of asphalt and aggregate mix. (26) Haul trucks convey hotmix to the MTV while both vehicles are on the adjacent slab. The MTV then transfers the hotmix to the paver machine while both move. This keeps the haul trucks off the prepared subgrade and allows the paver to move without stopping for each truck to back in.

This type of vehicle was used for construction of a new shoulders for a new runway at Indianapolis Airport. The contractor, Grady Brothers Inc. used a Barber-Green built MTV able to hold up to 70,000 pounds of material or two truck loads. Using this vehicle, a supply buffer was

maintained for the paver. As many as 25 trucks brought the asphalt in from two to three plants, each about ten miles from the worksite. The trucks remained on the concrete slab with the MTV where they dumped into the hopper in less than a minute. This allows the trucks to stay on the concrete and therefor ramps did not have to be constructed for the trucks to drive down onto the subgrade.

Production averaged 3000 tons per day with the paver and mobile transfer vehicle combination. With the MTV and a steady supply of trucks, the paver can proceed continuously. Non-stop paving increases production and yield a higher quality finished product.

CHAPTER 13

LASER GUIDED PAVERS

Conventional asphaltic paving practices usually require setting stringlines to set the grade for the pavers. This control method requires lengthy surveying crew set up and more time to accomplish the paving. Lasers offer time saving alternatives that also improve final grade control and overall quality. Reducing the amount of initial set up and nightly setup coupled with the increase in paver productivity makes laser use appealing to many contractors.

The use of lasers for grade control normally involves setting up one or more laser transmitters that send out rotating beams. Laser receivers and control systems are attached to pavers. The devices on the paver read the transmitted laser signal and can automatically adjust the screed height to the desired level. This allows the operator to fully control the thickness of the mat and make changes due to obstructions without slowing the paving process.

Recently Sarasota-Bradenton airport contracted with Gator Asphalt Co. to resurface their main 7000 foot runway.

(27) The original design called for conventional stringline paving with a centerline keel (crown) running the runway's full length with some minor vertical curves. The engineer's original design specified a slope down from the crown to the sides of 1 to 1 1/2 percent. Using stringlines, the pace of the work would have slowed to a point that the contractor would not have been able to pave the full width across the runway in one night. Employing stringlines and the original design would have required the contractor to:

1. Pave a leveling course in the crown and placing wedge sections of asphalt to form transitions of the asphalt to form transitional sections from the crown sides down to the old existing runway. This is necessary because of the requirement that temporary wedges be installed for aircraft safety, to avoid sharp drop offs.
2. Pave a surface course for each keel again with wedges on each side.
3. Mill out the transition wedges on each side and pave the 37 ft wide side sections simultaneously.

The contractor proposed a value engineering change that redesigned the final asphalt grades for laser guided pavers. Working with the Airport authorities, the designer and the Federal Aviation Administration authorities, the contractor won approval.

The new method enabled the Gator Asphalt Co. to pave full width each night across the 150 foot wide runway. Setting and resetting stringlines to work full width would have been nearly impossible within the five hours available for construction work each night. By using lasers to guide the pavers, the contractor estimated he cut 10 working days from the 110 day project.

CHAPTER 14

COMPUTER AUTOMATION

With there reduction in both cost and size, computers they have become a very common place part of nearly all segments of construction. This tendency toward more and more automation in work processes includes aircraft pavement construction. Currently most uses are directed more toward information tracking such as accounting information, personnel and equipment productivity, material receipt, and maintenance. (28) This trend will likely continue because of the real tangible benefits that contractors are seeing to these devices. More powerful software packages for scheduling and field office managerial functions will result in many more desk top and portable computers in the field over the next few years.

Many new computer applications are in various stages of research, development and implementation. New applications deal much more with improvement of the construction processes and less with using the computer as a managerial tool.

The most expensive and critical part of the paving process is the paver machine. Whether the work involves asphalt or portland cement concrete, maintaining proper control over the functions of the equipment is paramount in timely execution of the work progress and ensuring a quality pavement.

Many contractors and equipment manufactures are now producing new pavers or modifying existing ones to use computers and automate paver functions. As an example a Gomaco Co. has on the market a paver that incorporates many automation and computerization innovations that improve its production. (29)

The paver has three on-board computers that coordinate the machines functions. One computer positioned in at the operators station controls pavement alignment and profile. Sensors trace profile from stringlines on each side of the paver while alignment is traced from the left one.

The other two computers control the sequence of operations of the dowel bar inserter. One computer initiates the sequence of the cart distributing the dowels after the injection fingers have been withdrawn. The other activates the insertion and vibration of the dowels. This computer also measures the distance traveled by the paver

from sensors in the crawler and coordinates the triggering of the tie bar and dowel bar inserter operations based on those distances. In addition it controls the pan, and screed adjustments in transitions between tangents and curves. Control of the computer operation is fairly simple allowing the superintendent to adjust the spacing of random skewed joints.

The use of computers to automate the work process will likely continue. Although automation does cost a significant investment, the achievable higher quality and higher production will be a major impetus for future developments

PART III

FUTURE OF AIRPORT PAVEMENT CONSTRUCTION

What is the future of aircraft pavement construction? Does it make sense for contractors to invest in higher cost pavers that have high production, more crushers, and hot mix plants or should they gear themselves for a reduced workload in the immediate future? There is no clear answer to either of these questions but some past trends and current political atmosphere may be some indication of future workloads and what direction airport pavement construction may go.

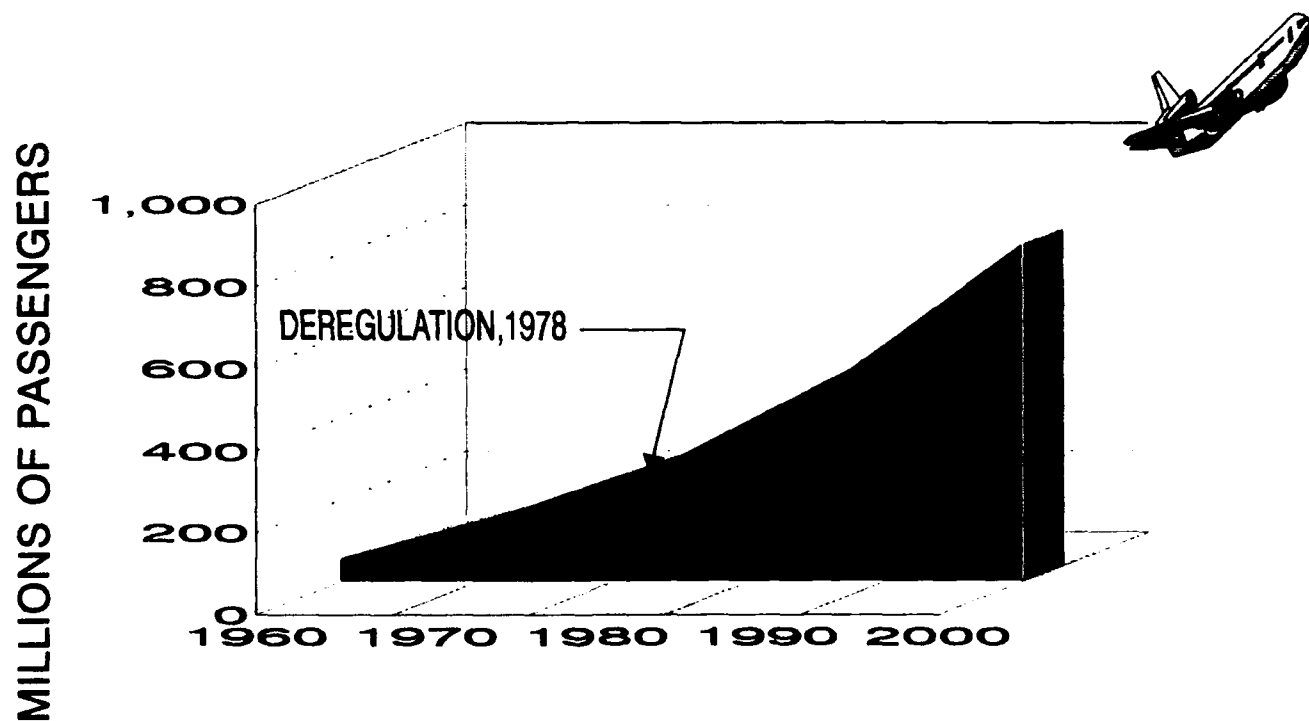
The Federal Aviation Administration's most recent capacity plan says that 62 of the 100 leading airports have proposed runways or extensions with a total price tag of \$6.5 billion. (30) With the public's dim view of higher taxes to pay for this and desire to reduce the national debt, normal federal funding may be difficult. Other traditional funding such as bond issues have equally little support. A new funding option opened due to 1991 federal legislation. (31) In this legislation airports were allowed to charge up to \$3 per passenger that transits through their airport. This money may be used for specific improvement projects approved by the Federal Aviation Administration. This fee could raise nearly \$1 billion per year for improvements.

As indicated in the introduction of this paper, airline deregulation played a major role in the increase in demand in aircraft use and therefor more need for runways, taxiways and aprons to support there aircraft. As can be seen in Figure (3), the rate of airline passenger traffic will continue to grow in the foreseeable future. (32) Although more passengers does not directly equate to more need for aircraft pavement it does indicate that changes in overall airport operations from a local, regional and national perspective will be required.

Many airlines are buying larger heavier aircraft that reduce their cost per passenger. This reduces their cost but will result in more fatigue in aprons and other pavement structures. More robust pavement designs and slab thicknesses may be required in the future. These new planes often have a larger footprint therefor more apron space may also be required in many areas.

When a local or regional government entity see overcrowding at their airport, their normal reaction is to find ways to expand there current facilities. This involves new runways, taxiways etc. In the extreme cases the decision may be reached to build a new complex such as Denver's new airport. The likelihood of this magnitude of

THE GROWTH IN AIRLINE PASSENGER TRAFFIC



"Airports Scramble to Keep Pace with Growth", Highway & Heavy Equipment

Figure 3

construction in the future is rather small. The construction industry should not rely on this type of massive projects for future livelihood. In many areas, expanding by construction of a new runway or extension of existing meets momentous opposition. Many people are calling for a long delayed new runway at Logan airport in Boston. The new runway would reduce aircraft delays that cost the airlines millions a year. Opposition centers mostly on lack of funding to support this project. (33) Long range plans call for construction of a new airport west of the city but once again funding is questionable

The answer to many congestion problems may not be expansion of new runways but looking for other solutions. One of these would ideally solve many problems at minimal cost. The Department of Defence through the Base Closure Process is closing many unneeded air bases. Many of these are near congested areas and may provide an inexpensive solution the overcrowding. These facilities could be used to support local commuter traffic or air freight functions that currently take up airspace and ramp space at many airports.

Two good examples of this is Logan airport and Miami International airport. As mentioned earlier Logan is overcrowded and needs to expand. While converting ex-military air facilities to civilian use will cost money it will be cheaper than constructing new ones. The Base Closure process will likely result in closure of Naval Air Station South Weymouth, less than 15 miles south of Logan airport. Use of this airport for commercial purposes would relieve much of Logan's overcrowding. The same holds true for Homestead Air Force Base. The base is in a ideal location to be used for local flights and other aviation uses.

Overall future of airport pavement construction is not as bleak as other construction areas. Construction of whole new airports is unlikely but repairing and expanding and modifying existing facilities will likely continue at a reasonable pace. Owners will likely use more sophisticated managerial tools reduce impact to airport operations and improve communications with the contractor during construction. Each competing contractor will have to use all of the innovations available to maintain there competitiveness and receive a part of the pavement construction work load.

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