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The development of plans for a national airport for Ankara, Turkey

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THE DEVELOPMENT OF PLANS FOR A NATIONAL AIRPORT FOR ANKARA, TURKEY

BY

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A

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CONTENTS

	Page
Acknowledgement	ii
Introduction	1
Importance of Airport	3
Selection of Airport Sites	5
The Field Layout and Runway Pattern	19
Clearing and Grading	21
Drainage	23
Types of Drains and Their Laying	25
Depth and Spacing of Drains	26
Surfacing	27
Runway Construction	29
Aprons	32
Taxiway	33
Hangars	34
Administration Building	35
Lighting System	36
General Information about Esenboga Airport	38
General Soil Characteristics	39
The Thickness of Pavement of Esenboga Airport	40
The Design of Esenboga Airport Drainage	45
Ankara Airport Lighting	47
Selection of Administration Building Site	48
Hangars	49
Economic Comparison and Conclusion	50

Appendix Page

Figure I - Runway Length reduction coefficient. 54

Table I - CAA classification of soil for airport construction 55

Figure II- Runway length above the sea level. 56

Figure III - CAA Minimum requirements for sub-base for concrete pavement. 57

Figure IV - Case of dual-tire load. 58

Figure V - Typical runway section 59

Table II - Earthwork and computation. 60

Diagram I - Profile of NE-SW instrument runway. 62

Diagram II - Typical cross-sections of NE-SW instrument runway 63

Diagram III - Mass curve of NE-SW instrument runway 67

Diagram IV - Proposed taxiway profile. 68

Master map I - 69

Bibliography 70

Vita 71

FOREWORD

"The present rapid development of general interest in aviation has brought to the front a new field of engineering. Development of the airplane has already reached a stage where the limit of its usefulness seems fixed only by the places which may be provided for taking off and landing. Due to the newness of the problem, not every one on whom responsibility rests recognizes the fact that the selection of the proper site and location for an airport is just as much an engineering problem as are its design and construction." (1)

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(1) Engineering News Record, p. 340, Sept. 6, 1948.

The Turkish government began construction of the Ankara-Esenboga airport in 1949. The present airport has many disadvantages over the ideal situation. The runways are located about 20 degrees off the prevailing winds of the wind rose, which creates crosswinds on the runways and is very unsatisfactory for a class 4 airport. The location of the runways introduced an uneconomical excavation problem.

The taxiways cross the main runways at four locations, which congests the take off and landing traffic. The overall length of the taxiway is great and adds more expense to the airport.

The purpose of this thesis is to show that a more economical and advantageous design could have been had for an airport in this locality.

The thesis submitted discusses this problem from several points of view as well as the actual location and design of runway and taxiway according to the new and modern specification of U. S. Civil Aeronautics Administration. Not considered in this paper is the design of hangars, administration building and other auxiliaries which is in fact a totally different field. That design is left for structural Engineers to work out.

IMPORTANCE OF AIRPORT

We live in a century in which the science of aviation is going through rapid progress and development. Every country on the globe is doing her best to increase the use of airplanes, both for civil and military purposes.

Today everyone is aware of the fact that, regardless of location, any city can be reached more quickly and with greater ease by airplane than by other known means of transportation. For this reason air transport has almost reached the point of being considered an indispensable medium of transportation in the life of a modern nation.

Today aviation has become a business of utmost importance, and like every other great industry it must do everything in its power to utilize facilities affecting safety, economy, uninterrupted service and reliability. This can only be done by providing adequate and well marked airports.

An airplane is on earth a greater time than it is in the air. So one easily foresees that the airports will play an important role in the future development of airplanes and of air transportation. Without a field to take off of and to land on, there can be no local flying anywhere. Just as railways must have stations and ocean going liners must have harbours and docks, so it is necessary for airplanes to have airports. The present progress of air travel and of air-mindedness of people reveals that it will be even more important for aircraft to possess airports than for other means of transportation to have terminals. As a general rule in transportation the importance of convenient terminal location varies inversely as the time required for transit. Hence it should be obvious that terminal location is of more importance in air transport than in any other form of long-distance transportation. This viewpoint throws a new light on the subject of airports.

Today every city wants to be on an airline just as it wanted to have railroads some time in the past. Cities which recognize this fact and build airports to meet the sky traffic will develop and grow up with new sources of wealth. On the other hand, those that ignore airplanes and air transportation will find themselves in exactly the same position as the cities that some generations ago ignored the railroad. For one city more or less makes little difference to the airline, but an airline makes a lot of difference to that one city. Choosing a site for the airfield; preparing it for use; erecting buildings and installing power equipment are vital problems which a city should carefully work out. A bad take off or a bad landing have considerable psychological effect on passengers, sightseers and pilots. On the other hand the feeling of reliability and safety in modern airports adds greatly to the enjoyment of the flight and tends to popularize this mode of transport.

Certainly, then, the local airport should be a subject worthy of most careful consideration by all interested in the growth of their city. The question of safety is very important if flying is to become a commonly accepted means of travel. Safety will demand the establishment of airports to a much greater degree than now anticipated. They must be of right kind and located in the proper places to do the most good.

SELECTION OF AIRPORT SITES

Site selection is a very important factor in the design of an airport. There is a variety of factors governing the selection of an airport site which should be carefully investigated to obtain efficiency of operation, safety, and economy in cost of construction. The neglect of one single factor in locating an airport may result in unjustified expenditures and more important than this, it results in inefficiency and danger. Selection of the airport site should be preceded by a careful study which will take into consideration the purposes which the airport will serve and the growth and shifting of population in the locality to be served.

For the establishment of an airport, it is always necessary to choose several possible sites and make a thorough investigation of each. It is only after a careful study of each particular location that the engineer can make the final decision. Once an airport has been constructed, its location must usually be regarded as permanent as the cost of moving to a new and more suitable one would be prohibitive.

The factors that enter into the selection of an airport site are discussed separately as follows:

I. Size: The size of an airport depends upon the types of machines and their performance characteristics, amount of traffic expected, altitude above sea level, features of the surrounding property. Heavily loaded commercial freight and passenger airplanes require a somewhat larger field than the lighter loaded and privately operated ones. Obviously, the character of the surroundings will have an important bearing on field size and will be discussed later.

The size of airports varies from 50 acres to 1000 acres, the average airport covering an area of about 250 acres. In other words, the area of a flying field should be of sufficient size for the performance requirements which are:

A. Taking off distance:

The take off distance is the distance traveled by an airplane to attain flying speed. The length of runway required depends upon the size of machine, ability and experience of the pilot, wind and field. Under average condition the distance traveled by an airplane to obtain flying speed is 300-1000 ft.

B. Climbing to the critical height:

This is the height to which the pilot climbs before he levels off into horizontal flight. This height usually depends upon the weather and surrounding conditions.

C. Gliding to the ground from the critical height:

This is the distance required in case of engine failure or some other trouble which obliges the pilot to land without power.

D. Landing run:

The field must have its runways of sufficient length to accomodate the above mentioned four items. In other words, the length of the field must be at least equal to the sum of the horizontal distances covered in accomodating the performance requirements.

For accepted runway lengths for various airport classifications see Diagram II page 56in Appendix.

Generally there are three principal factors which affect runway length requirements and they are:

a - Winds and their direction

b - Elevation above sea level

c - Surface condition

Winds of noticeable velocity in the direction of the runway reduce the take off and landing run. If we know the "Unstick Speed" (1)

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(1) The speed at which the wheels of an aircraft leave the ground at the end of the take off run.

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and the wind velocity, we can determine the effect of the wind on runway length as follows:

$L_w = L_o \times R_r$ (2)

in which L_w = Runway length for any wind velocity

L_o = Runway length for zerowind velocity

R_r = Runway length reduction coefficient as obtained from (Figure 1 in appendix)

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(2) Foresch, Charles and Prokosch, Walter, Airport Planning, p. 112, 1946

The runway length for zero wind is shown in table I, page 8, for various types of aircraft.

The second important factor which affects runway length is the elevation above sea level. Runways should be lengthened according to the below formula:

$$L = L_s + \frac{A}{4} \quad (3)$$

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(3) Froesch, Charles and Prokosch, Walter, Airport Planning, p. 112, 1946

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where

L = Length required at particular site in feet.
L_s = Recommended length for class of airport at sea level.
A = Altitude of site above sea level.

This relationship is shown graphically in Figure 2 in appendix.

Another important factor influencing the size of an airport and runway length is the surface condition of the landing area or runway surface as affected by rain, snow or ice. Although rain has been known to increase

TABLE I (1)

	Landing Speed	Safe Runway Length 3 + 15*	Safe Runway Length 3 + 12
Piper, Standard Trainer	38	2040	
Piper, Super Cruiser	45	2750	
Aeronca Arrow	48	2550	
Ercoupe	48	2550	
Thunderbolt Amphibian	53	3390	
Stinson Reliant	48	3140	
Beechcraft D17R	50	2200	
Beechcraft 18S	61	2400	
Lockheed Saturn	80	4800	
Douglas DC-3	68½	4020	
Curtiss-Wright CW-20E	80	5085	
Douglas DC-4	80	6830	5280
Lockheed Constellation	80	7720	6180
Boeing Stratocruiser	80	10020	8190
Douglas DC-7	80	13080	10452

Taken from CAA

* It appears that the factor 15 is too high when applied to four-engine aircraft. The use of 12 as a factor gives a better approximation of safe runway length requirement for such aircraft, as shown in column.

(1) Froesch, Charles and Prokosch, Walter, Airport Planning, p. 43, 1946

the coefficient of adhesion of tire tread to runway surface, the reverse is true as a rule. Snow, if not too light or too wet, provides good retarding action in landing, but ice reduces the coefficient of braking friction. When the airport has a soft sod surface or the runways consist of loose gravel or cinders, causing greater rolling resistance, the normal take off run will be appreciably lengthened. Smooth concrete or asphalt surfaces are preferable and are almost universally used except where a hard sod or a well-drained surface is available.

II. Meteorological conditions: Among the important elements to be considered in the primary selection of an airport are the meteorological conditions to be expected. These are usually constant around a city. But the presence of hills, valleys and high structures usually affect the direction of winds, amount of rainfall, frequency of fogs, occurrence of floods and other important factors to be studied. The weather bureau records of the locality should be consulted so that complete information on this subject may be obtained. This investigation should cover not only the field site itself but also the air routes into it.

In the primary selection of routes it is always desirable that aircraft should operate along a perfectly straight line. But, due to the ranges of high mountains through which the pilot must fly, the absence of adequate intermediate landing fields, or some meteorological obstacles, it may be found necessary to depart from this desirable straight line.

The important meteorological factors influencing the choice of airways and airports are:

A. Wind

The direction, velocity and frequency of prevailing winds are most essential in selecting a site. They are important in two ways: first, in the arrangement of the airport take off and landing areas so that the airplane or airship may take off and land into the wind the greater part of the time, and second, in locating the airway so that conditions are generally favorable for operation. They affect the arrangement of the building and the size and general shape of the field. Strong winds may cause damage to planes parked outside of the hangars and may necessitate the increase of storage facilities.

Airplanes must take off and land flying directly against the wind. Cross-wind landings can be made in light planes and in heavier planes by expert pilots, but this practice is not recommended, especially in aircraft used for public transportation. When the airport is not available for landing in all directions, the longest strip should be aligned with the direction of the prevailing wind.

B. Rain and Snow

Slow and uniform rains are usually desirable for soil stabilization, prevention of dust, and green growth in untreated fields. Continuous or intense rainfall is undesirable for an airport site because it softens the soil, causes wind and danger where field drainage is not good. Thus heavy, concentrated precipitation needs to be considered and will be discussed later under "Drainage".

Snow when melting, causes more trouble than heavy rains. Moreover, snow has a bad effect on operation for landing as well as for taking off. Snow covers the marking system on airports and makes it ineffective; also, it changes the appearance of the surroundings, and makes it difficult for the pilot to locate the airport. However, a site should be free from accumulations of snow drifts.

C. Fog, Haze, and Clouds

Nothing is more annoying in the operation of airplanes than fog.

Low fogs hinder safe landing and take off, while high fogs cause delay in arrival. Therefore, an airport should not be located in a fog belt. This is especially so for commercial planes that operate at fixed times. It is a well known fact that one side of a town is often much more free from fog than another side. The presence of a stationary body of water will usually be the cause of fog, and if such bodies of water are not used as a seaplane base, airports should be away from them.

Fog may be defined as "a cloud resting on the earth's surface and consisting of moisture which has condensed upon particles of dust" while haze is "any atmospheric density created by the presence of dust, smoke or causes other than moisture." Haze is usually produced in industrial districts, particularly where soft coal is used as fuel. Sites in such districts must be avoided, as haze is a cause of landing accidents and is objectionable for it prevents pilots from locating the field.

Clouds are not influenced by local conditions and are usually constant around a city. Therefore they are not as important for locating the field as fog and haze, but, certainly they are of utmost importance in operation.

There are other meteorological conditions influencing choice of airports such as storms, temperature, humidity and pressure, but they are of less importance than the ones mentioned above.

III. Types of soil and its drainage. Considerable attention should be given to the types of soil that are found at airport sites. Landing speeds of modern airplanes require smooth and firm soil to prevent accidents. The ground should be firm under all weather conditions. Soil which drains naturally and which is suitable for the growth of tough, all-year grass should always be preferred. The most desirable soil for airports is the one containing a reasonable amount of porous material such as gravel or decomposed rock combined with a suitable binder clay. When the soil of an airport is of friable character dust may form in dry weather under the action of traffic. Haze caused by dust is a source of accidents and should be prevented at any cost.

Table I in the appendix in page gives the Civil Aeronautics Administration classification of soils for airport construction, from which classification sub-base is determined.

Classification is based on sieve analysis of the portion of the sample passing the No. 10 sieve. When a sample contains a material coarser than the No. 10 sieve in amounts equal to or greater than the maximum limit shown in the table, a raise in classification may be allowed. If the subgrade is an R_a material, no sub-base will be required under the concrete pavement.

The drainage of airport landing fields, roads and runways is an important problem and one which must be considered before the site is finally decided upon. For the cost of drainage may, conceivably, be a deciding factor in the choice. Further reference will be made later to this question.

IV. Topography. A site approximately level is essential for an air field, otherwise the cost of leveling may be prohibitive. The field site should be tolerably free from ditches and other surface irregularities. It should be either entirely clear or should be capable of being cleared of any brush or heavy growths without increasing excessive cost. Ground having a slope 1 - 2% is most desirable. However the slope may vary from 5 - 25%. In such a case, more importance will have to be considered to construct the grade of the landing and take off areas or runways to agree with the desirable limit, than the grade of other parts of the field.

In artificially drained fields too flat a surface is undesirable because excavation cost for laying drains increases considerably. The location of the field with respect to its surroundings should be such as to be unaffected by flood water. An airport should not be located near high hills which cause dangerous air currents. Furthermore they are themselves a serious obstruction.

The surrounding topography of an air site must be of such a nature as to allow future expansion of the port at a reasonable cost. The country around the air field should be open enough to facilitate forced landings in case of engine failure. This space is also necessary for the possible future enlargement of the port.

When airports are located near distinctive landmarks such as streams, channels, railroads, highways and similar topographic features, these help the pilot to identify the port. These features are of more help to flyers who come to the port for the first time.

V. Surroundings or approach areas. Airport sites should be as free as possible from high buildings, chimneys, tall towers, transmission lines, overhead electric cable lines, groups of trees and high hills. Any other natural or artificial obstructions that are as likely to interfere with air currents as well as with the approach of airplanes, should also be removed if possible. Otherwise, such obstructions must be well lighted at night to prevent accidents.

Consideration must also be given to the possibility of the surrounding territory becoming built up in the future. Buildings that may be constructed should at least be ten times their height away from the side of the field. Territory just behind the field buildings could be covered by less severe restrictions.

The CAA recommends that the approaches to landing areas shall be clear within a glide path of 20 to one from the end of the usable area of the field for its class I landing facilities, and 30 to one for its classes

II, III, IV, and V airports with the provision that instrument landing runways shall have a glide path of 40 to 1. These ratio are minimum, and it is obvious that the flatter the angle of approach to a runway, the better. In this respect, a minimum of 50 to 1 glide path is not only desirable but preferable for scheduled commercial air transportation.

These glide paths or zoning ratios are for sea level or near sea level altitude fields. Correction should be made above the sea level.

VI. Accessibility.* Airports should be located as close as possible to the center of the city. Because of the difficulty in securing adequate open spaces for airports in some cities, the average distance for some several hundred airports today is about 3 miles from the center of the city. The larger the municipality the greater is this distance, because the difficulty of securing adequate acreage near the heart of any city is in direct ratio to the size of that city. Moreover, if the airport is to be used for commercial purposes, the site should be as near the city in traveling time as the ground cost will permit. It must be kept in mind that there are instances of European airports having been abandoned because they were too far from the city or too difficult to reach. In short, due to different considerations of law, topography, city planning and economy this distance is always kept to a practical minimum.

It is always an unquestionable advantage for an airport to be adjacent to a railroad, or a main highway. An air traveler does not want to lose much time getting to the heart of the city. For this reason airports should not be more than 10 miles from the down town district and a fast and comfortable means of transportation should be available. This not only reduces the cost of transportation of construction materials but also increases the accessibility of the field. Thus, it results in added vital income to the city and its airport.

If the airport is not located on the main highway, roads should be built from the air terminal to the main highway. The airport should be bounded by streets, preferably owned or under the control of the owners of the airport. Wide thoroughfares should lead off from the airport in all directions. The site should have adequate telegraph and telephone connections and the location should be such that water supply and electricity can be installed at a moderate cost. Nearby gasoline and oil supplies and a post office are usually desirable.

VII. Cost. The amount of cost is one of the important elements regarding the selection of an airport site. Usually, after a thorough study of possible sites, the one for which the construction cost is lowest is chosen to be most satisfactory one. For this reason cost is a governing factor for the final selection of an airport site.

The different items that enter into the total cost of the project are:

a - Cost of land.
b - Cost of earthwork.
c - Cost of surfacing and drainage.
d - Cost of removing hazards and other obstructions.
e - Cost of the provision of transportation and traffic facilities.
f - Cost of necessary utilities.
g - Cost of different buildings.

a - Cost of land: The amount of money that is spent for the purchase of the land is always a considerable part of the initial capital. The unit value of land decreases with an increase of the distance from the center of the city. However, a saving in land costs for airports that are located far from the center of the cities may prove a complete failure. *Operating costs of the sites increase with the increase of distance from the city. *

b - Cost of earthwork: This includes the cost of grading and leveling. It is almost impossible to find a site without mounds, hollows or ditches. Such mounds should be removed and ditches filled.

c - Cost of surfacing and drainage: Concrete aprons in front of hangars and other buildings are always necessary. In soil of little bearing value, artificial runways of some sort become necessary.

The cost of drainage of the site varies considerably with the kind of soil. Heavy clay land may cost two or three times as much to drain as sandy and other lighter lands.

d - Cost of removing hazards and other obstructions: The cost of clearing the site varies considerably with the different sites. The cost includes removing of trees, buildings, old foundations, telegraph poles, and so forth.

e - Cost of the provision for transportations and traffic facilities: If the airport is situated at some isolated spot, the field must be connected to the town by a good highway. This considerably increases the initial cost, the amount depending upon the distance of the airport from the town and upon the type of surface to be used.

Special bus services which are operated by airport personnel increase the first cost and operating expenditures. However, a good super highway and an efficient bus service are always necessary to attract big crowds and make people air-minded.

f - Cost of necessary utilities: This includes all the expenditures for installing electricity, telephone, water supply, sewers and supply of gasoline and oil. The cost of necessary utilities which are mentioned varies considerably depending largely upon the distance of the airport from the source of supply.

g - Cost of different buildings: The cost of different buildings and hangars will depend upon the function and class of airdrome. At the beginning, enough hangar space and accomodations must be provided to satisfy the traffic. Additional hangars and other buildings may be constructed as traffic increases.

The factors that affect the location of an airport have been tabulated by R. L. Davison according to their relative values as follows: [1]

(1) Principles of City Planning by Lohmann, p. 146.

Requirements of the flyer	Relative value
1 - Freedom from dense river fogs	8
2 - Freedom from ground mist	5
3 - Freedom from smoke condition	6
4 - Freedom from snow drifts	1
5 - Freedom from air travel interference	4
6 - Prospective neighborhood development	2
7 - Freedom from objectionable air currents and eddies .	1
8 - Approaches - satisfactory area under take off . . .	3
9 - Favorable prevailing winds with reference to runways.	4
10 - Other factors affecting safety	4

Requirements of the public	Relative value
1 - Location with respect to axes of air travel	8
2 - Distance and direction from the source of air travel business	7
3 - Distance from the geographic center.	4
4 - Distance from center of population	8
5 - Distance from rail terminals	2
6 - Distance from water terminals	1
7 - Distance from post office	6
8 - Distance from hotel center	5
9 - Distance from economic center.	3

Requirements of the public	Relative value
10 - Distance from financial center	3
11 - Distance from center of airplane manufacturing industries	3

THE FIELD LAYOUT AND RUNWAY PATTERN

The general layout of airports is governed by prevailing winds, kind of airport to be established, shape of the site located and many other considerations. An airport can be of any shape, provided the field meets the performance requirements that are discussed in the previous pages.

In obtaining logical arrangement, provision should be made for future hangars, shops, garages, and other buildings, all of which have to be considered in the original plan, otherwise the neglect may prove expensive later.

In general, the buildings and any other obstructions to flying should be grouped together within the angle of the least frequent take offs where practicable space between hangars, buildings, and other structures should be provided in order to reduce the fire hazards. The administration building, which customarily includes the manager's office and the control tower, as well as other auxiliaries, should be located in such a way that it overlooks the field. The question of arrangement of each structure will be discussed later.

It is essential that the buildings be located adjacent to a road or a main highway, if possible, so that automobiles will not have to cross the flying field. Roadways should be provided to connect each of the buildings with the main road and with each other.

In planning the field layout no plan can be set up as an ideal for all cases, but with a careful study of the performance requirements, direction of the prevailing wind, shape of the selected site, surroundings of the field, including obstructions and accessibility, the layout can be designed easily.

The author believes also that the study of the plans of different airports that are shown in most books as well as the items mentioned in this dissertation, will help a great deal in deciding upon a specific design.

CLEARING AND GRADING

When a site is selected and the general arrangement is worked out, the first step to be taken is clearing the site of its obstructions.

Clearing consists of the removal of trees, brush, bushes, tall grass and other obstructions existing at the site. One method of removing trees would be by cutting the trees below the surface and then removing the stump. This method is rather inefficient due to the length of time required. In general, the use of creeper tractors to pull out the entire tree is a more efficient and more economical way than the previous method. The advantage of this method is that the roots of the trees are pulled out as well. Dynamiting which is even a cheaper way should not be used, because it may loosen the ground for some distance and make a soft spot in the field.

The debris of organic materials, if present, should either be removed or completely burned. All stones and boulders should be cleared from the surface and removed. Old fences existing on the field must be cleared off.

All depressions that are present on the surface of the site must be filled. A mixture of sand and gravel should be used for filling materials. This mixture not only provides a good hard base, but also helps drainage of the field.

After the field is well cleared of trees and other obstructions the entire property will have to be graded. The grading of the surface has to be carried on concurrently with the drainage operations. The grading system should be planned so that the excavated material is moved the shortest possible distance. In such a case the use of tractors and scoops has been shown to be economical. Where the fill is great, the use of a hydraulic system is preferable due to the prohibitive cost of filling by any other method. Some say that the most economic grade line for a railroad is the one which keeps the cost of operation and the cost of construction at a minimum. This is not wholly true for airport construction, because there are some other things which we have to consider in the construction of an airport.

In grading, care should be taken not to bury the top fertile soil with the sub-soil. This can best be done by removing all the top soil to a depth of about 6 inches and piling it to one side. Then after careful grading and compacting, the top soil is evenly distributed. The final surface should be bladed and dragged.

The question of turf is very important and is one of the best protections yet devised against dust, which is an irritating factor in summer operation.

The kind and quantity of seed to be planted should be determined by an agricultural expert. The seed should be distributed with a wheeled seeder, not by hand, so that the distribution of the grass will be even.

DRAINAGE

The problem of drainage is one of the most important items in the design of airports. Good drainage promotes safety in air transportation and materially increases the value of the air terminal. Badly drained flying fields cause damage to all the surface during heavy rainfall, besides rendering landings dangerous.

In designing the drainage system for a site a careful investigation of weather and frost conditions must be made. It is also necessary to have a careful study of the soil characteristics, for the draining qualities of a field depend upon the texture and structure of the soil as well as the character of the underlying sub-soil. The proper way to determine this is to make an analysis of undisturbed soil taken from holes at various points on the site. These test holes should be at least 4 to 5 feet deep and should be of sufficient depth to reach a porous sub-soil if any exists. It is only after such information is obtained that the extent to which artificial drainage must be carried on is determined.

The problem of drainage should include a surface drainage system to take care of run-off water as well as subsurface drainage to take care of the percolating water and lowering the water table. Surface drainage is necessary for the prevention of surface erosion and for the elimination of floods. Flooding conditions may be eliminated by placing surface drains at points of concentration such as at the foot of runways and aprons.

Before designing the drainage system for an airport, rainfall statistics should be obtained in order to determine the probably maximum for the locality. These records are of more value to the designer if they are for a great number of years. The drainage system may be designed to remove in 2 or 3 hours the probable intensity of the hourly rainfall that will not be exceeded more than once a year, but many engineers believe such expense unnecessary and design the drains for the removal of maximum rains of 24 hour duration.

When the rate of rainfall, the time allowed for removal of the water, and the run-off factor are known, it is possible to estimate roughly the capacity of the drain by the following formula:

$$Q = \frac{RiA}{T+t}$$ (1)

Where: Q = required capacity of drain in feet per second.
R = coefficient of run-off for ground surface served by drains.
i = rate of rainfall inches per hour.
A = estimated area of ground surface served by drain in acres.
T = duration of rainfall in hours (assume 1 hour in airport design).
t = time allowed for removal of rainfall after end of storm, in hours (assume between 3 and 24 hours by the designer and the chief director of the airport)

(1) Sharp, H. Oakley; Shaw, G. Reed; Dunlop, John A; Airport Planning, p 27, 1946.

The value of R depends on the character of the ground surface. For a paved runway or impervious roof, R may be assumed to be 0.8 to 0.9; and for sodded surface, R may be taken as 0.2.

TYPES OF DRAINS AND THEIR LAYING

Drains may be of porous pipe, tile, broken stone, rubble or of some other material. Tile drains, however, are the most satisfactory ones and always should be preferred. Airport drains should be strong enough to withstand the impact produced by landings of heavy airplanes. Vitrified clay drains break under the hammer effect of traffice, but are very strong against acid actions. Concrete, although somewhat elastic, is attacked by acids and alkalies and disintegrates easily.

The tiles should be laid with the ends fitting as close together as possible and so as to rest firmly on the bed of the trench. It is desirable to have a width of joint not greater than 1/8" for sandy soil and 1/4" for clay soil. Generally, the tiles are placed directly on the bottom of the trench with no special covering around the joints. When tiles are placed in material draining poorly, it may be desirable to surround them with loose sandy soil if such is available. In saturated fine sand or loam it may be necessary to use tar paper or other suitable materials around the joints to prevent soil particles from entering the tile. Curves may be made by fitting the ends of tiles which deviate most from being straight, or by chipping the edges of the tiles on the inside of the curve and fitting the inside edges closely and covering the outside edges with bars.

After the tile is laid on its foundation, it is covered with a fine pervious material 1/4 to 1/2 inch in size to a height varying from 18 to 40 inches. Then a layer of 12" thickness is added consisting of coarse, angular gravel, crushed stone or slag 2 - 3 inches in size. This combination forms the usual design for side drains used in practice.

DEPTH AND SPACING OF DRAINS

The depth at which subdrains should be laid depends upon the type of soil, temperature and intensity of heavy rainfalls. Generally, drains should extend in depth to an impervious subsoil, if such exists, with three feet from the top to the ground, when no such impervious layers exist, drains should extend to a depth of about 3' in clay and 5' in silt. As fine texture soils present a greater resistance to percolation, it is evident that drains in them must be placed at a shallower depth than in the case of sand or gravel. In some localities freezing is the main factor governing depth.

The spacing of drains depends upon soil characteristics, amount and frequency of rainfall and the depth at which the drains are placed. The shallower the depth, the closer the drain lines must be placed. A spacing of 50 to 100 feet will be found to be about the correct distance for average conditions.

Particular attention should be given to the drainage of the more central parts of the field, that is the parts in front of the hangars and runway. (With regard to disposal if the ground around the field is flat and outlet is not available for the discharge of the drainage, the question becomes a little more complicated.) In such a case, it may be necessary to construct a canal system around the field and located as close as possible to the property line. The drain outlet may then be arranged to discharge into the canal at various points and the water allowed to gradually seep away into the porous subsoil.

SURFACING

The type of surface desired for an airport depends upon the kind of airport that is to be established and the activities to be expected on the field. In the case of emergency fields a good stand of grass may be practical, while in another, hard surface runways would be the logical solution. An airport designed and constructed to serve heavy commercial planes operating throughout the year should have hard surfaced runways. A sodded landing field is only satisfactory for light planes.

A brief discussion of different types of runway surfaces is made in "Runway Construction".

The main part of the landing ground, however, is usually of grass and where a good turf exists and can be maintained it forms an ideal airport surface. When the turf is rather thin, it may be improved by discing with cutters, sufficiently to permit seeding. Where no turf exists or is not worth saving, the ground should be plowed to a depth of about 18 inches, harrowed to the point of pulverization, and then the required amount of seed is added. The kind and quantity of seed to be planted should be determined by an agricultural expert. The seed should be distributed with a wheeled seeder and not by hand, so that the distribution of the grass will be even. In all cases, the grass should be tough and specially chosen.

The question of turf is very important and is one of the best protections yet devised against dust, which is an important factor in summer operations. Moreover, it offers a pleasant appearance to the airport.

Besides grass, landing areas may be oil treated to prevent dust occurrence, which is one of the many methods rapidly coming into use. However, these methods cost more in first cost and maintenance than where grass is used. Furthermore they require a more expensive drainage system. In general a grass surface is to be preferred where the traffic permits it.

RUNWAY CONSTRUCTION

The principles governing the design and construction of runways are the same as those governing the design and construction of highways. Careful consideration must be given to the preparation of subgrade and shoulders, adequate surface, and surface drainage.

In designing a runway, the impact of the airplane as well as its dead load, must be taken into consideration. However, at present there is a lack of agreement on the amount of impact delivered to a surface by the landing plane due to the unsatisfactory methods now in use for measuring impact. Some authors state that the maximum load upon a runway is static, impact being small. Others proclaim that impact runs as high as 3.5 times the static loads.

Generally there are two groups of runway pavements:

1 - Non-rigid type or flexible type of pavement.
2 - Rigid type of pavement.

Non-rigid type or flexible type of pavements include all the bituminous types, such as those constructed with emulsions or cutbacks.

The total thickness of flexible type of pavement depends upon variations in the soil characteristics, natural soil moisture and climate, degree of compaction and so forth.

There are many design formulas for the flexible type of pavement. Nowadays most of the larger airplanes require dual-tire landing gear rather than single tire systems. Goldbeck's formula may be applied to dual-tire loadings. [1]

---

(1) Sharp, H. Oakley; Shaw, G. Reed; Dunlop, John A., Airport Engineering, p. 68, 1946

$$t = \sqrt{\frac{KW}{M} - 2SL_1 - \pi L_1 L_2 + \left(\frac{2S + L_1 + L_2}{2}\right)^2} - \frac{2S + L_1 + L_2}{2}$$

(see figure 4 in appendix)

in which:

t = thickness of pavement
W = Maximum wheel load on a pair of dual wheels
M = Maximum pressure intensity on subgrade
P = calculated equivalent uniform pressure on subgrade
$K = \frac{M}{P}$
$L_1 = \frac{1}{2}$ the major axis of ellipse of tire contact area
$L_2 = \frac{1}{2}$ the minor axis of ellipse of tire contact area
S = Center to center spacing of dual tires
A = Area of equivalent subgrade pressure

Dual-tire wheel loading is less severe than single-tire loading due to the load spread over wider area.

The rigid type of pavements are portland cement concrete, soil cement, certain asphaltic concrete, and water-bound macadam. "The research of recent years has provided rather definite information for the design of rigid pavements to withstand the stresses caused by the wheel loads of motor vehicles, but information of a similar character relating directly to the design of airport runway surface of the rigid type is not yet available.

Highway research has shown further that when a wheel load is applied to a rigid pavement, the magnitude of the stress developed in the pavement by that load will be determined by the magnitude of the vertical component of the load, the position of the load with respect to the edge of the pavement slab, the area over which the load is distributed to the pavement surface and by certain physical characteristics of the material in the pavement and in the sub-grade which supports the pavement." (1)

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(1) Principles of Highway Construction as Applied to Airports Flight Strips and Other Landing Areas for Aircraft, by Public Roads Administration, p.

It is easy to notice that the conditions that obtain when the landing wheel of an airplane is supported by a rigid runway surface differ materially from those which have been studied in the highway research of recent years.

It is very important that rigid pavements do not deflect or bend when the subgrade changes. Mr. Clifford Older, who was the chief engineer of the Illinois State Highway Department, developed a formula for determining the thickness of a rigid pavement constructed of concrete.

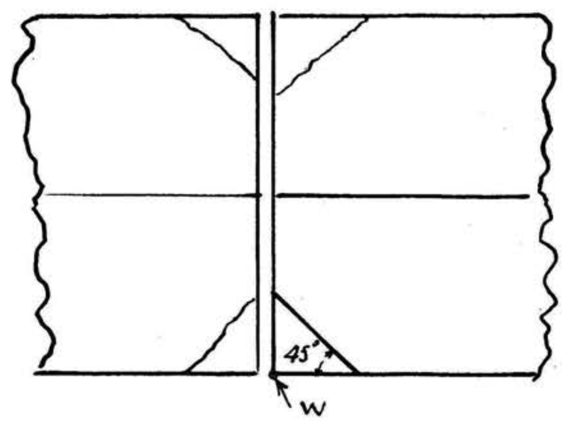
Investigations and tests showed that all cracks made a 45° angle with the edge of the road slab as shown in the Figure

Older formula (1)

$$t = \sqrt{\frac{3W}{S}}$$

in which

t = edge thickness in inches
W = max. wheel load plus impact
S = allowable flexural stress in concrete in pounds per square inch



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(1) Sharp, H. Oakley; Shaw, G. Reed; Dunlop, John A., Airport Engineering, p. 82, 1946

APRONS

An apron may be defined as the portion of an airport, usually paved, immediately adjacent to hangars and other buildings, used for parking, loading, and unloading of aircraft. The size and character of apron must be consistent with the class of airport under consideration. A properly designed apron should fit the following items:

1 - It should provide for the arrival and departure of each plane to the loading point independently of the movement of other planes.

2 - It should provide for the independent loading and unloading of numbers of planes simultaneously with provison for increased capacity for future requirements.

3 - It should provide a separation of incoming and outgoing passenger and freight traffic.

4 - It should facilitate passenger transfer between planes.

5 - It should provide protection to passengers from the weather, from the blast of the airplane slip stream, and from the roar of airplane motors.

6 - It should, by its inherent design, reduce the amount of maneuvering of planes at the loading point to a minimum

TAXIWAY

A taxiway may be defined as a paved strip over which aircraft may taxi to and from the landing area, runways, or aprons of an airport. The size and character of taxiways depend upon the class of airport under consideration. Taxiways must be of a width sufficient to allow a plane to remain on the taxiway surface under all wind conditions and should be arranged so as to allow a plane to move from either end of the runway to permit a rapid clearance of the runway for other aircraft in order to increase the efficiency of operation.

HANGARS

Among the buildings used in an airport, the hangars are very important. Thus, before designing such a structure several points must be considered carefully. The types, size, location and number of hangars needed for an airport depend upon the extent, nature, and importance of the flying field. However, all hangars must be economical in first as well as maintenance cost, well lighted, resistant to fire and economical to heat. Like all other buildings the cost of hangars varies with the type, size, location and climate.

Size of hangars:

In deciding upon the size of a hangar, it is necessary to obtain information on the dimensions of the airplanes that are likely to be housed in them, so that neither waste of space nor impossibility of housing future visiting airplanes may occur. Where no specific information can be obtained, it is advisable to choose large sizes of hangars.

ADMINISTRATION BUILDING

The administration building should be located in such a place that it overlooks the field.

Thus, the control tower should be placed on the roof of this building. The necessity for the controller to be able to see all aircraft operating on or in the immediate vicinity of the airport makes proper location of the control tower the prime requirement.

In designing the administration building, it should be kept in mind that adequate terminal accomodations together with necessary facilities for the traveling public must be provided. These accomodations may include offices, passenger waiting room, ticket office, pilot quarters, toilets, mail and freight storage, post office, and restaurant. It is an excellent plan to design a structure that includes all of these accomodations. However, the building may be extended from time to time when traffic develops.

Certain of the activities may be moved to new buildings located nearby if necessity demands. Therefore, a space should be provided near the administration building for future development.

The buildings should be spaced to reduce the danger of fire. It would be even better if the administration building is fire proof.

LIGHTING SYSTEM

Whether or not airports are used for scheduled night flying, provision should be made to facilitate the safe landing of aircraft during darkness. Unfavorable winds and other delays frequently cause aircraft to arrive over an airport after darkness. To land on the field under these conditions may present hazards.

An aviator who flies at night has to rely for his course on a well lighted landing field.

The cost of the best system is small compared to its service in extending the use of the airport throughout 24 hours daily. A single serious accident, aside from the danger to human life, due to inadequate lighting, might involve more expense than the entire cost of the best lighting facilities. This indicates the importance of an adequate lighting system. Since the design and installation of the proper lighting for aviation is the job of an electrical engineer, only a brief discussion of airport lighting will be made.

The equipment necessary for a completely lighted airport is:

1 - Airport beacon

2 - Illuminated wind tee - direction indicator

3 - Illuminated wind cone

4 - Boundary lights

5 - Range lights

6 - Flood lights

7 - Signal lights

8 - Ceiling projector

9 - Hangar flood lights and roof marking

10 - Obstruction light

11 - Runway contact lights

12 - Apron flood lighting

GENERAL INFORMATION ABOUT ESENBOGA AIRPORT

Geographic situation:

Ankara - Esenboga Civil Airport is situated 948 meters above sea level, 32 kilometers northeast of the city of Ankara. The traveling time from city to airport is 20 minutes, the route being through a congested section of the city. This airport is owned and operated by the state.

Short history of the locality:

As it is shown on the topographic map of Esenboga there was a military airport at this locality more than 20 years and at present that airport is used for local needs. The new modern construction was started in 1949.

The main object of this new airport:

The main object of this new construction is to control air traffic among the continents and in Turkey itself.

Meteorological situation:

Direction, velocity and variation of prevailing winds are shown in the wind rose on the map. (See the master map, page 69 in appendix)
For information on the temperature, intensity of rain, snow, frost and fog, use is made of the bulletins of the state weather bureau.

In Esenboga the maximum and minimum temperatures vary between + 35C. and - 28C. or 95°F. and - 18°F.

GENERAL SOIL CHARACTERISTICS

In general the soil consists of a brown silty clay, a white brown silty clay and a brown clay silt, underlaid in most parts with a yellow sandy clay. The thickness of the top layer varies between 1.00 and 1.50 meters. The liquid limit of the silty clay is between 38 and 49 and the plasticity index is between 20 and 30. The shrinkage limit varies between 9 and 18. For the brown clay silt the liquid limit is between 40 and 50, the plasticity index between 20 and 30 and the shrinkage limit between 11 and 20.

The modified proctor densities for these three kinds of soils are 100#/ft^3, 115#/ft^3 and 113.5#/ft^3 respectively.

The compaction in the field will be 95% maximum modified proctor density under paved areas and 90% on shoulders.

Without compaction the probable bearing value on the ground will be 2 T/sq. ft. or 4000#/ sq. ft.

THE THICKNESS OF PAVEMENT OF ESENBOGA AIRPORT

Assuming a 300,000# plane which is recommended future design standard of the C.A.A. -

Design procedure:

1 - Selection of runway directions parallel to wind rose data.

a - Topography determines general location.

2 - Taxiway locations - not closer than 700 feet from runways. (See the master map, page 69 in appendix.)

3 - Soil data indicates shrinkage factor of from 20 percent to 30 percent. Earthwork has been developed with a shrinkage factor of 25 percent. (See page 60 in appendix.) This has been chosen because specific data on these soils is lacking and it is not possible for us to secure more complete soil data in the allotted time.

Pavement thickness development follows:

Nowadays most of the larger airplanes use dual-tire landing gear rather than the single tire system. Because of this, Goldbeck's dual-tire formula will be used for this design.

$$t = \sqrt{\frac{KW}{M} - 2SL_1 - \pi L_1 L_2 + \left(\frac{2S + L_1 + L_2}{2}\right)^2} + \frac{2S + L_1 + L_2}{2}$$

Where:

$W = 140{,}000$ pounds (gross load)
$M = 2$ ton/sq. ft. $= \frac{2 \times 2000}{144} = 27.8$ (28 is used)
$P = \frac{28}{2} = 14$
$K = \frac{M}{P} = \frac{28}{14} = 2$
$S = 48$ inches)
$2L_2 = 18$ inches) According to Armco Drainage Products Association.
$2L_1 = 34$ inches)

$$t = \sqrt{\frac{2 \times 140{,}000}{28} - (2)(48)(17) - (3.14)(17)(9) + \left(\frac{2(48) + 9 + 17}{2}\right)^2} - \left(\frac{2(48) + 17 + 9}{2}\right)$$

t = 46.7 inches or 118.6 cms
(See figure 5 in appendix page 59)

The thickness of reinforced concrete	=	10 inches =	25.4 cms
The thickness of granular subbage	=	12 inches =	30.4 cms
The thickness of compacted subgrade	=	24.7 in. =	62.7 cms
Total		46.7 inches=	118.6 cms

In the United States the difference in cost between concrete and bituminous material, in many cases makes it more economical to use bituminous runways. The low first cost of bituminous runways sometimes offsets the advantages that concrete runways have over them.

Some of these advantages are:

1 - Low maintenance costs of concrete
2 - Concrete is less subject to temperature changes
3 - Concrete is less affected by subgrade damage.

However, in Turkey the situation is reversed. In America the bituminous materials have the lower first cost. In Turkey concrete has a lower first cost, because all bituminous materials must be imported, where the concrete products are manufactured there.

This gives concrete all the advantages over bituminous materials in runway construction, therefore we will design a concrete runway for Esenboga Airport.

The thickness selected for the three component parts of the entire pavement has been selected in conformity with the best American practice and for a particular job would be determined by an economic comparison.

The Finished Cost per Square Yard of Concrete Pavement

<u>10 inches concrete pavement</u>

Cement = 3.03 cu ft = 94 x 3.03 = 283 pounds = 2.83 x 200 = 566 kr.

Water = 4.37 cu ft = 62.4 x 4.37 = 273 pounds = =

Sand = 6.664 cu ft= 2.65 x 6.664 x 62.4 = 1100 pounds = 11.00 x 7 = 77 kr.

Stone = 12.936 cu ft = 2.65 x 12.936 x 62.4 = 2100 pounds = 21.4 x 5 = 107.0 kr

750.0 kr

Yield = 27.000 cu ft = 1 cu yd

The cost of 100 pounds of cement = 200 kurus

" " " " " " sand = 7 kurus

" " " " " " stone = 5 kurus

The cost of per cubic yard of concrete pavement = 750.0 kurus

" " " " square yard of concrete " = 750.0 x .278 = 208.0 kr.

" " " mixing, placing and curing, etc. = 208.0 kr.

The total cost of per square yard of 10" concrete pavement = 416.0 kurus

<u>12 inches granular subbase</u>

1 cu yd of stone = 4460 pounds

1 sq yd of stone = 4460 x .333 = 1490 pounds

The cost per sq yd of stone = 14.90 x 5 = 74.50 kurus

" " of the placing and compacting = 74.50 kurus

The cost of 1 sq yd of granular subbase is = 149.00 kurus

Total finished cost of per square yd of concrete pavement = 565.0 kurus = $2.36

THE FINISHED COST OF PER SQUARE YD. OF BITUMINOUS PAVEMENT

5 inches hot mix (2 applications)

Total mineral aggregate	(coarse aggregate) (fine aggregate) (mineral filler)	0.92
	asphalt cement	0.08
	Yield	1.00

3.5 gal/sq yd is used

The cost of one gallon of asphalt cement = 16 kurus

The cost of 3.5 gallons of asphalt cement = 56 kurus

The cost of 1 sq yd of stone of 5 inches thickness = 31.0 kurus

The cost of 1 sq yd of bituminous pavement = 87.0 kurus

The cost of mixing and placing = 87.0 kurus

The total cost of 5 inches hot mix is equal to 174 kurus

8 inches bituminous macadam (6 applications)

2 @ 0.5 gal/sq yd = 1.00

2 @ 0.35 gal/sq yd = .70

2 @ 0.3 gal/sq yd = .60

2.30 gal/sq yd

The cost of 2.3 gallons of asphalt = 36.8 kurus

The cost of 1 sq yd of stone of 8 inch thickness = 4460 x 0.222 x 0.05 = 49.6 kurus

The cost of mixing and placing = 86.4 kurus

The total cost of 8 inches bituminous macadam = 172.8 kurus

9 inches compacted stone

The cost of 1 sq yd of stone = $\frac{4460 \times 0.25 \times 5}{100}$ = 111.6 kurus

The cost of placing and compacting = 111.6 kurus

The total cost of 9 inches compacted stone = 223.2

The total cost of finished bituminous pavement = 569.8 kurus = $2.38

From the above calculation, it is seen that the concrete pavement is more advantageous in first cost as well as requiring less maintenance.

This design has assumed the sodding of all areas not covered by runways or taxiways after a suitable top soil has been placed to sustain proper growth. The selection of the proper grasses for this is a local problem and one out of the scope of this dissertation.

THE DESIGN OF ESENBOGA AIRPORT DRAINAGE

Studies of runoff from airport areas have not been conducted for a long enough period of time to indicate the need for any more reliable method than those used for storm sewers. For the Drainage system of Esenboga the Burkli-Ziegler formula is used.

$$Q = \frac{AIR}{T+t}$$

in which

A = 331 acreas (calculated from the map)
I = 1.5 inches/hour
R = 0.7
t = 2 hours
T = 1 hour

$$Q = \frac{(331)(0.7)(1.5)}{1+2} = 116 \text{ ft}^3/\text{sec}$$

The size of culvert used is 42 inches or 106.68 cms.

The culvert is located in such a way that the distance between the top of culvert and ground elevation is minimum 2 feet under the landing strip and 3.5 feet under the runway.

The location of the culvert is shown in cross section of the landing strip. It is located between station 11 + 00 and 12 + 50. (See page 64,65 in appendix.)

A catch basin is located at the upper end of the portion of the culvert under the landing strip (station 12 + 50).

In this design concrete pipe is used because it is cheaper. Concrete pipe is manufactured in Turkey while other pipes must be imported. All types of pipe for the loadings designed require the same depth of cover, so pipe cost alone is the only economic factor.

Lacking specific data to the contrary, since the drainage pattern is conducive to rapid runoff, no provision has been made for any type of underdrainage system. It is the belief of the author that none would be required.

ANKARA AIRPORT LIGHTING

Esenboga Ankara airport is designed for instrument landing at night and in all weather conditions. Therefore, the following lighting equipment should be provided at the Ankara airport. (1)

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(1) They are recommended by C.A.A.

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1 - Airport beacon

2 - Boundary lights

3 - Range lights

4 - Obstruction lights

5 - Illuminated wind cone

6 - Apron floodlighting

7 - Traffic pistol light

8 - Landing area floodlight

9 - Illuminated wind tee

10 - Ceiling projector

11 - Runway contact lights

12 - Approach lights

No attempt has been made to locate any of the needed lighting facilities as these are not part of this thesis.

SELECTION OF ADMINISTRATION BUILDING SITE

The administration building has been located with reference to centralization with respect to all possible runways as well as future expansion of hangars, aprons and other related utilities and in addition, thought has been given to accessibility to roads and parking facilities. (Refer to master map page 69 in appendix.)

HANGARS

Only anticipated probable needs for the immediate future have been provided for, but ample room has been left for additional hangar space on the right side of the administration building for any possible needed future expansion. (See notations on extra sheets of appendix section.)

ECONOMIC COMPARISON & CONCLUSION

In general C.A.A. requirements have been adherred to as closely as possible with economy, usefulness and accessibility in mind.

In general and specific design of the main NE - SW instrument runway and taxiway system has been worked out and other location indicated by dotted lines. (See master map, page 69 in appendix.)

The drainage area affecting the taxiway and main runway has been determined in the usual manner by plainimetering the area indicated on the map as necessary to be provided for in this plan.

Auxiliary drainage facilities will be required for other runways and enclosed areas, but the problem is the same except for details.

Balancing the earthwork quantities:

This has been done by the customary procedures of cut-and-try methods, using the grade limitations given by the C.A.A. Specification for this type of airport construction (refer to page 62 in appendix) Cross-sections has been calculated from the map and station has been taken at every 50 meters. Overhaul has been calculated on the basis of 1 ~~m3~~ cubic meter hauled 30 meters. This has been selected as most nearly conforming to the accepted practice of using station-yards in American controlled work. (refer to page 69 in appendix.)

An economic comparison between the two generally accepted surfacing materials used in airport runways, viz - portland cement concrete and bituminous concrete or other bituminous treated surfaces, has been made (see page 41 for this data).

The foregoing airport design is considered to be the the most economical that could be had for this locality. Had the Turkish government spent a little more time in preparing the design for the Ankara airport, it would have had a more advantageous design at a lower cost than that of the present airport.

Summarizing the advantages the airport design in the thesis has over the present airport above:

1 - Runways are located along the wind rose:
(See the master map, page 69 in appendix)

The runways of the above airport are located about 20 degrees off the prevailing winds of the wind rose, which creates crosswinds on the runways and is very unsatisfactory for a class 4 airport. Airplanes used for public transportation must take off and land flying directly against the wind. Cross-Wind landings can be made in light planes and in heavier planes by expert pilots, but this practice is never recommended, especially in aircraft used for public transportation. For this reason the above airport is not safe, and it should be kept in mind that the question of safety is very important if flying is to become a commonly accepted means of travel. safety will demand the establishment of airports to a much greater degree than now anticipated.

2 - A minimum of overall taxiway length is obtained:
The taxiway should be designed so as to reduce the taxiing distance from the administration building to the point of take off. Excessive taxiing is an economic waste which should not be tolerated in airport planning. The amount of money that is spent for the construction of taxiways is always a considerable part of the investment. The overall taxiway length of the above airport is almost twice the overall taxiway length of the foregoing airport design.

3 - Taxiways do not cross the runways:
The taxiways of the above airport cross the main runways at four locations, which congests the take off and landing traffic and is very unsatisfactory for safe operation. In the foregoing design taxiways never cross the runway.

Besides the taxiing distance from the administration building is less as compared with the above design.

4 - This airport can be classified as a class 4 airport. The main object of the above airport design is to control air traffic among the continents. It means that this airport should be designed according to the requirements for the heaviest planes. The length of the runways are not enough for safe operation for this kind of airport. The foregoing airport layout is designed as a class 4 airport which is satisfactory and safe for long international flights and according to the new and modern specification of United States Civil Aeronautics Administration.

5 - More space is available for the future expansion of operational facilities. In determining the location of the administration buildings and hangars, space should always be provided near the administration buildings and hangars for future development.

In the foregoing design the administration building and hangars are so located that any future development can easily be provided.

6 - Better location of the Administration Buildings:
The administration building should be located in such a place that it overlooks the field. Thus, the control tower should be placed on the roof of this building.

In the foregoing design the following items are considered and provided:

a - The future expansion of the administration buildings and hangars.

b - Ample area for roadways.

c - Ample area for car parking.

d - Convenient access to main highway.

e - Central location with respect to runway.

f - A configuration is provided.

g - Favorable orientation with respect to topography, prevailing winds.

The features of the airport designed in this thesis that make it more economical than the present airport are:

1 - Less excavation is needed for the runway, taxiways, and the administration buildings. The amount of money that is spent for the excavation is always a considerable part of the investment. In the above design this item is not considered at all and has this disadvantage from the economical point of view, which is of prime importance in selection of runway site and it should be considered. In the foregoing design a site for a runway pattern is selected so that the most economy can be obtained.

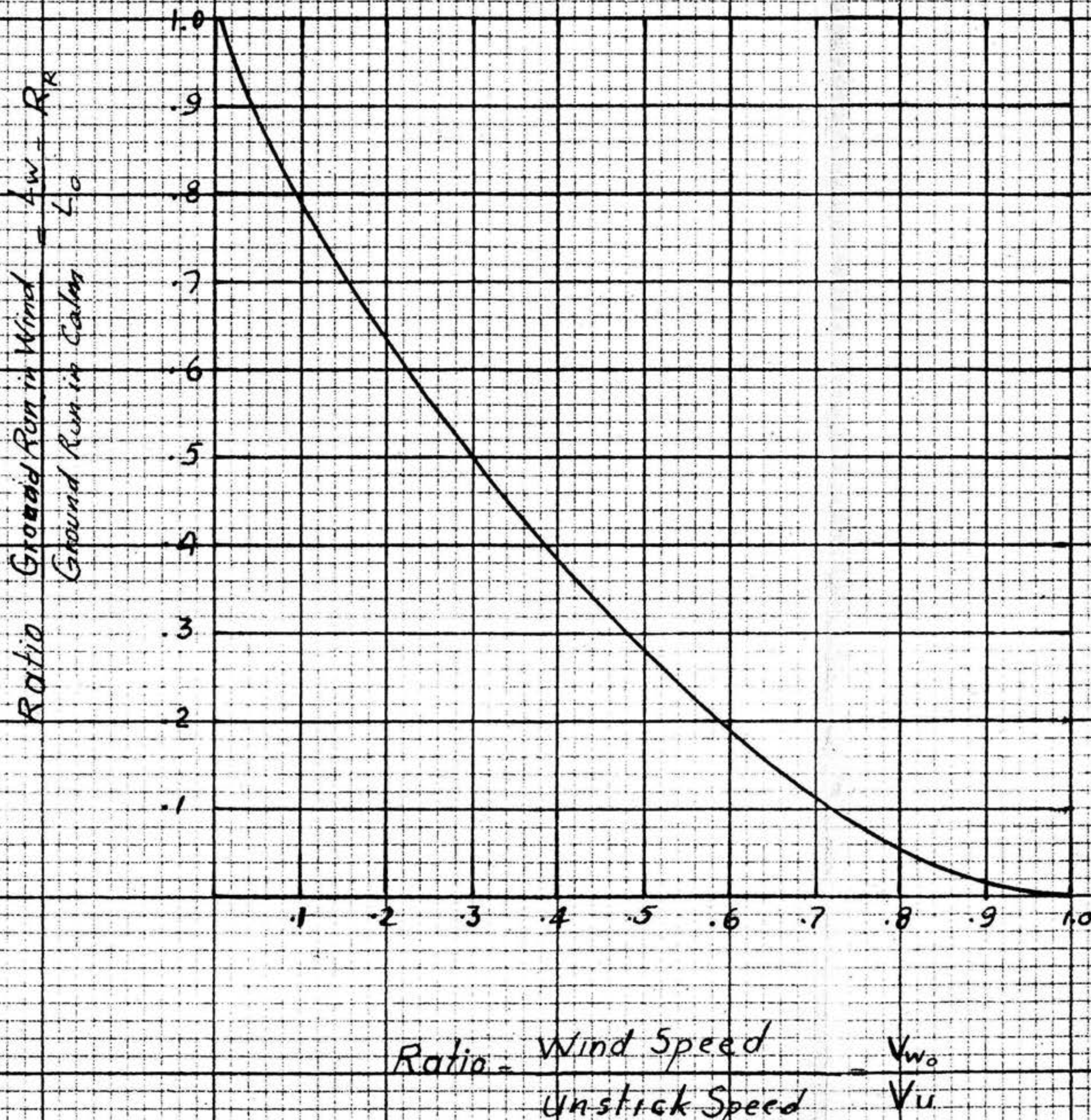
2 - The overall length of the taxiways is considerably less. As I mentioned above, the amount of money that is spent for the construction of taxiways is always a considerable part of the investment. As the overall length of taxiways decreases, the amount of money that is spent for the construction will decrease. The overall taxiway length of the above airport is almost twice the overall taxiway length of the foregoing airport design, as money paid for the construction of the above taxiways will be almost double as compared with the foregoing design.

In many of the engineering problems, as in the case of the Ankara Airport, more economy and advantages can be had by a more thorough investigation of the conditions of the problem encountered.

APPENDIX

FIGURE I

Runway Length reduction coefficient



TAKEN FROM CAA

FIGURE I

TABLE I

CAA classification of soil for airport construction

	Soil Group	MECHANICAL ANALYSIS				Liquid Limit	Plasticity Index	SUBGRADE CLASS			
		Retained On No.10 Sieve	Material Finer Than No.10 Sieve					Good Drainage		Poor Drainage	
			Coarse Sand Percent	Fine Sand Percent	Combined Silt & Clay Percent			No Frost	Severe Frost	No Frost	Severe Frost
GRANULAR SOILS	E-1	0-45	40+	60-	15-	25-	6-	R1a	R1a	R1a	R1a
	E-2	0-45	15+	85-	25-	25-	6-	R1a	R1a	R1a	R1a
	E-3	0-45			25-	25-	6	R1a	R1a	R1a	R1a
	E-4	0-45			35-	35-	10-	R1a	R1a	R1a	R2a
	E-5	0-45			45-	40-	15-	R1a	R1b	R1b	R2b
FINE GRAINED SOILS	E-6	0-55			45+	40-	10-	R1a	R2b	R2b	R2b
	E-7	0-55			45+	50-	10-30	R1b	R2b	R2b	R2c
	E-8	0-55			45+	60-	15-40	R1b	R2c	R2c	R2d
	E-9	0-55			45+	40+	30-	R2b	R2c	R2c	R2d
	E-10	0-55			45+	70-	20-50	R2b	R2c	R2c	R2d
	E-11	0-55			45+	80-	30+	R2c	R2d	R2d	R2e
	E-12	0-55			45+	80+		R2d	R2e	R2e	R2e
	E-13	MUCK AND PEAT - FIELD EXAMINATION						Not Suitable for subgrade			

CAA CLASSIFICATION OF SOILS FOR AIRPORT CONSTRUCTION - CONCRETE RUNWAYS, TAXIWAY, APRONS AND RUNWAY ENDS

TAKEN FROM CAA

TABLE-1

FIGURE II

Runway length above the sea level

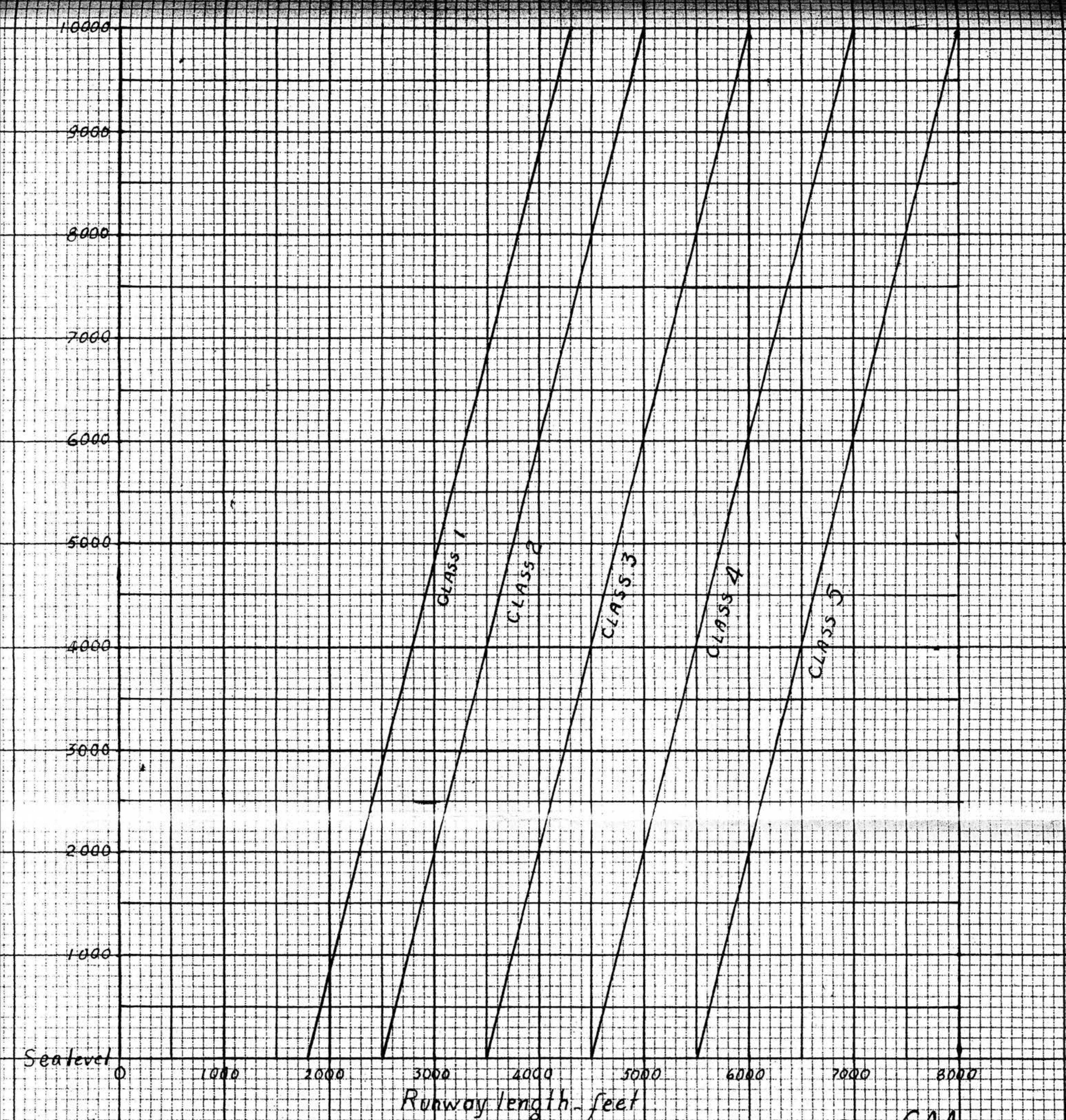
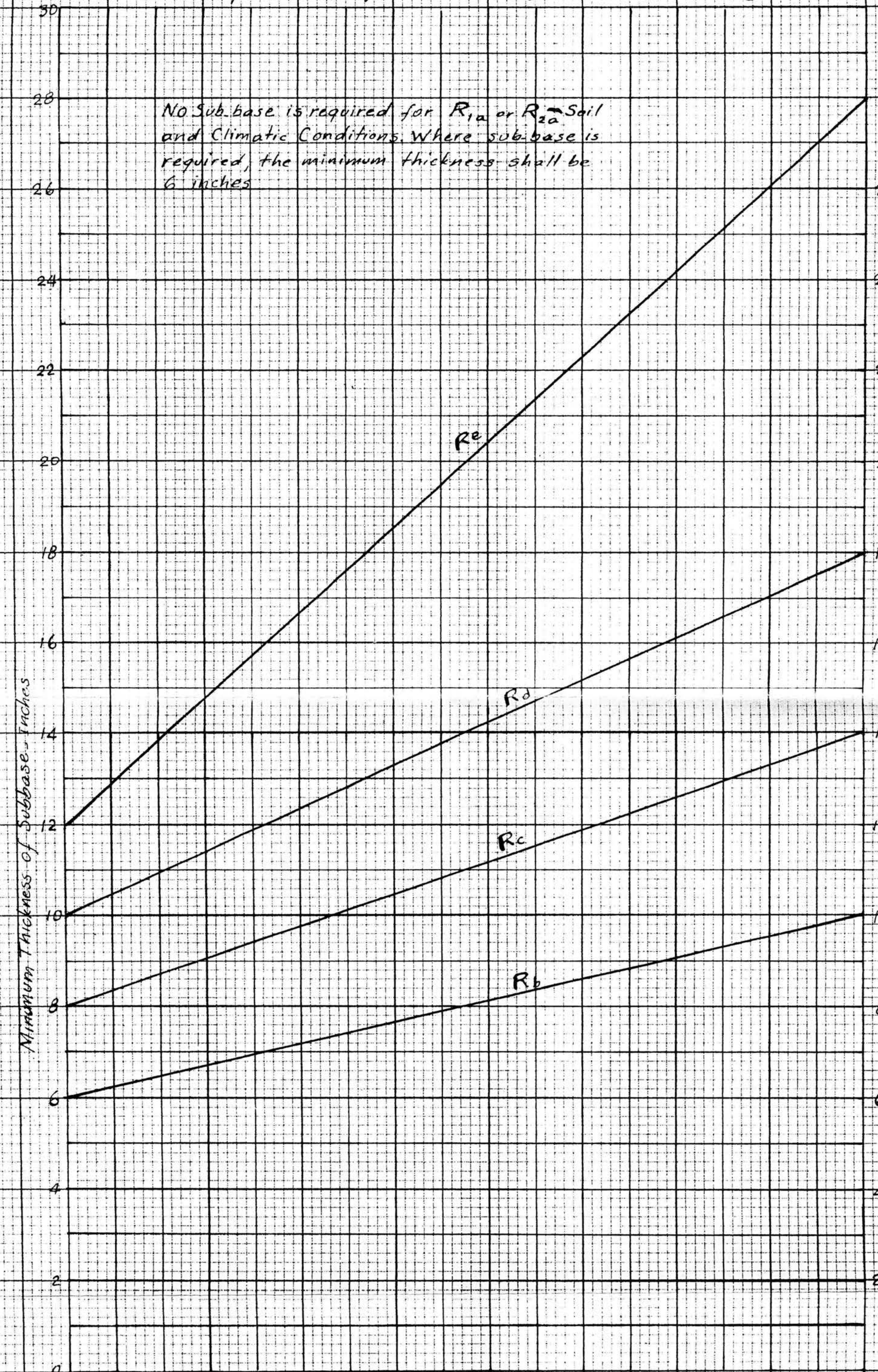


FIGURE 2

TAKEN FROM CAA

CAA Minimum requirements for sub-base for Concrete Pavements

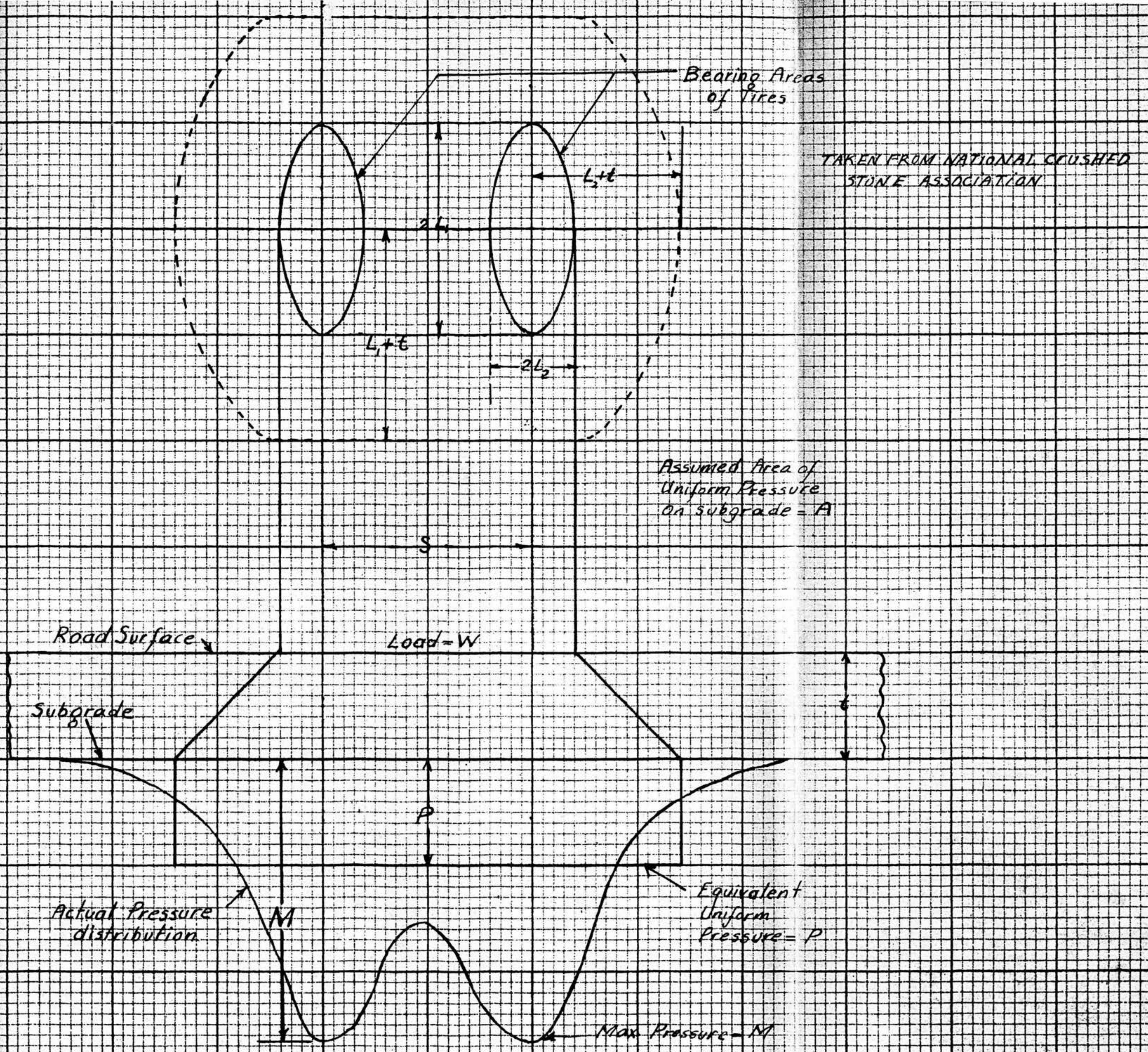


Taken From CAA

FIGURE 3

FIGURE IV

case of duel-tire Load



Bearing Areas of Tires
TAKEN FROM NATIONAL CRUSHED STONE ASSOCIATION
L2+t
2L1
L1+t
2L2
Assumed Area of Uniform Pressure On subgrade = A
S
Road Surface
Load = W
t
Subgrade
P
M
Actual Pressure distribution
Equivalent Uniform Pressure = P
Max Pressure = M

FIGURE 4

FIGURE V

Typical runway section

℄
160 Meters
3 M.
61 Meters
3 M.
A
B
Grade 1%
Grade 1%
Slope 10:1
Slope 10:1
A'
B'
A
B
25.4 Cm
Reinforced Concrete.
30.5 cm
Granular Subbase shall be placed in compacted Layers
Compacted Subgrade
62.7 cm
Natural Soil
A'
B'

FIGURE 5

TABLE II

Earthwork and computation

1

STATION	%	TANG. ELEV.	V C	GRADE ELEV.	CUT END AREAS	CUT SUM END AREAS	CUT DIST.	CUT PRODUCT	CUT CU. Ms.	FILL END AREAS	FILL SUM END AREAS	FILL DIST.	FILL PRODUCT	FILL CU. Ms.	% SHRINK	FILL & SHRINK	MASS
0+00	+0.06	100.00	0	99.70	44	120	50	6000	3000	16	16	50	800	400	25	500	0
+50	"	100.40	0	100.40	76	176	"	8800	4400	0	0	"			"		+ 2500
1+00	"	100.75	0	100.80	100	208	"	10400	5200	0	0	"			"		+ 6900
+50	"	101.10	0	101.15	108	148	"	7400	3750	0	12	"	600	300	"	375	+12100
2+00	"	101.50	0	101.30	40	67	"	3350	1675	12	36	"	1800	900	"	1125	+15475
+50	"	101.90	0	101.40	27	47	"	2350	1175	24	64	"	3200	1600	"	2000	+16025
3+00	"	102.20	0	101.60	20	28	"	1400	700	40	116	"	5800	2900	"	3625	+15200
+50	"	102.60	0	101.75	8	12	"	600	300	76	144	"	7200	3600	"	4500	+12275
4+00	"	102.95	0	102.00	4	8	"	400	200	68	148	"	7400	3700	"	4625	+ 8075
+50	"	103.40	0	102.40	4	12	"	600	300	80	120	"	6000	3000	"	3750	+ 3650
5+00	"	103.70	0	103.00	8	40	"	2000	1000	40	60	"	3000	1500	"	1875	+ 200
+50	"	104.05	0	103.65	32	72	"	3600	1800	20	28	"	1400	700	"	875	− 675
6+00	"	104.40	0	104.20	40	80	"	4000	2000	8	20	"	1000	500	"	625	+ 250
+50	"	104.80	0	104.30	40	84	"	4200	2100	12	24	"	1200	600	"	750	+ 1625
7+00	"	105.15	0	104.85	44	72	"	3600	1800	12	28	"	1400	700	"	875	+ 2975
+50	"	105.50	0	105.00	28	48	"	2400	1200	16	24	"	1200	600	"	750	+ 2900
8+00	"	105.90	0	105.60	20	40	"	2000	1000	8	28	"	1400	700	"	825	+ 3350
+50	"	106.12	0.027	105.65	20	40	"	2000	1000	20	48	"	2400	1200	"	1500	+ 3475
9+00	"	106.50	0.108	106.10	20	44	"	2200	1100	28	44	"	2200	1100	"	1375	+ 2975
+50	+0.35	106.67	0.022	106.20	24	48	"	2400	1200	16	56	"	2800	1400	"	1750	+ 2700
10+00	"	106.85	0	106.30	24	59	"	2950	1475	40	146	"	7300	3650	"	4567.5	+ 2150
+50	"	107.00	0	106.50	35	63	"	3150	1575	106	246	"	12300	6150	"	7687.5	− 940
11+00	"	107.20	0	106.35	28	64	"	3200	1600	140	280	"	14000	7000	"	8750	− 7054
+50	"	107.35	0	105.85	36	46	"	2300	1150	140	296	"	14800	7400	"	9250	− 14200
12+00	"	107.50	0	106.10	10	14	"	700	350	156	296	"	14800	7400	"	9250	− 22304
+50	"	107.65	0	106.40	4	4	"	200	100	140	340	"	17000	8500	"	10600	− 31204
13+00	"	107.83	0	106.25	0	0	"			200	496	"	24800	12400	"	15500	− 41704
+50	"	107.95	0	105.90	0	0	"			296	628	"	31400	15700	"	19625	− 57204
14+00	"	108.00	0	105.60	0	4	"	200	100	332	600	"	30000	15000	"	18750	− 76329
+50	"	108.10	0	105.95	4	8	"	400	200	268	400	"	20000	10000	"	12500	− 94479

Earthwork and computation

2

STATION	%	TANG. ELEV.	V.C	GRADE ELEV.	~ CUT ~ END AREAS	SUM END AREAS	DIST.	PRODUCT	CU Ms.	~ FILL ~ END AREAS	SUM END AREAS	DIST.	PRODUCT	CU Ms.	% SHRINK	FILL & SHRINK	MASS
15+00	″	108.40	0	107.30	4	36	50	1800	900	132	156	50	7800	3900	25	4850	-106779
+50	″	108.55	0	107.90	32	132	″	6600	3300	24	24	″	1200	600	″	750	-110,729
16+00	″	108.70	0	108.70	100	280	″	14000	7000	0	0	″			″		-108179
+50	″	108.80	0	109.20	180	352	″	17600	8800	0	0	″			″		-99779
17+00	″	109.00	0	109.40	172	292	″	14600	7300	0	0	″			″		-90929
+50	″	109.10	0	109.15	120	212	″	10600	5300	0	4	″			″		-83620
18+00	″	109.30	0	109.15	92	210	″	10500	5250	4	4	″			″		-78379
+50	″	109.50	0	109.50	128	248	″	12400	6200	0	0	″			″		-73129
19+00	″	109.65	0	109.80	120	292	″	14600	7300	0	0	″			″		-66929
+50	″	109.60	0	110.05	172	332	″	16600	8300	0	0	″			″		-59629
20+00	″	109.80	0	110.25	160	222	″	11100	5550	0	4	″	200	100	″	125	-51329
+50	″	110.10	0	109.90	62	102	″	5100	2550	4	44	″	2200	1100	″	1375	-45904
21+00	″	110.18	0.007	109.70	40	128	″	6400	3200	400	40	″	2000	1000	″	1250	-44729
+50	+0.27	110.00	0	110.10	88	240	″	12000	6000	0	0	″			″		-42779
22+00	″	110.50	0	110.95	152	300	″	15000	7500	0	0	″			″		-36779
+50	″	110.60	0	110.85	148	240	″	12000	6000	0	22	″	1100	550	″	688	-29299
23+00	″	110.80	0	110.80	92	168	″	8400	4200	22	66	″	3300	1650	″	2060	-23987
+50	″	110.90	0	110.65	76	80	″	4000	2000	44	148	″	7400	3700	″	4623	-21847
24+00	″	111.00	0	110.20	4	20	″	1000	500	104	208	″	10400	5200	″	6500	-24478
+50	″	111.20	0	110.20	16	44	″	2200	1100	104	164	″	8200	4100	″	5125	-30472
25+00	″	111.30	0	110.65	28	92	″	4600	2300	60	96	″	4800	2400	″	3000	-34497
+50	″	111.40	0	111.00	64	118	″	5900	2950	36	66	″	3300	1650	″	2060	-35197
26+00	″	111.60	0	111.20	54	94	″	4700	2350	30	74	″	3700	1850	″	2312	-34309
+50	″	111.70	0	111.25	40	70	″	3500	1750	44	116	″	5800	2900	″	3625	-34269
27+00	″	111.80	0	111.05	30					72							-36144

DIAGRAM I
Profile of NE-SW instrument runway

DIAGRAM II

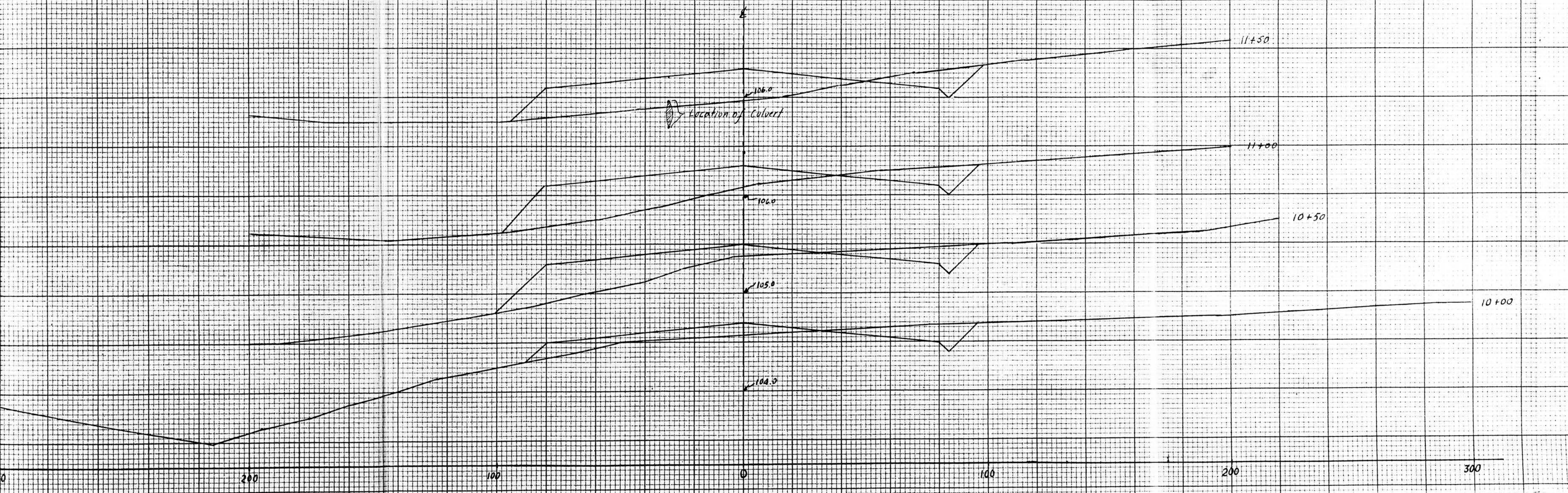
Typical cross-sections of NE-SW instrument runway

1

CROSS SECTIONS OF NE-SW RUNWAY
℄
1+50
100.0
1+00
100.0
0+50
100.0
Vertical Scale
2 meters = 1 inch
Horizontal Scale:
0+00
100.0
20 meters = 1 inch
300
200
100
0
100
200
300

Typical cross-sections of NE-SW instrument runway showing the Location of culvert

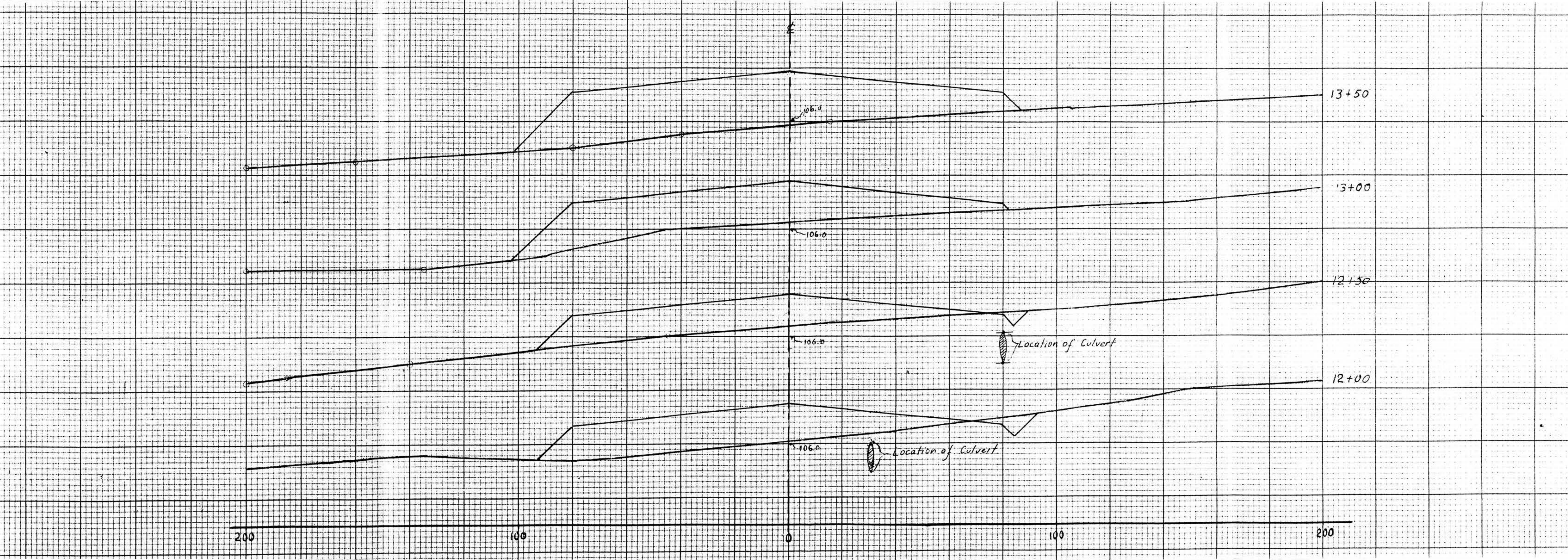
2



℄
11+50
106.0
Location of Culvert
11+00
106.0
10+50
105.0
10+00
104.0
200
100
0
100
200
300

Typical cross-sections of NE-SW instrument runway showing the Location of culvert

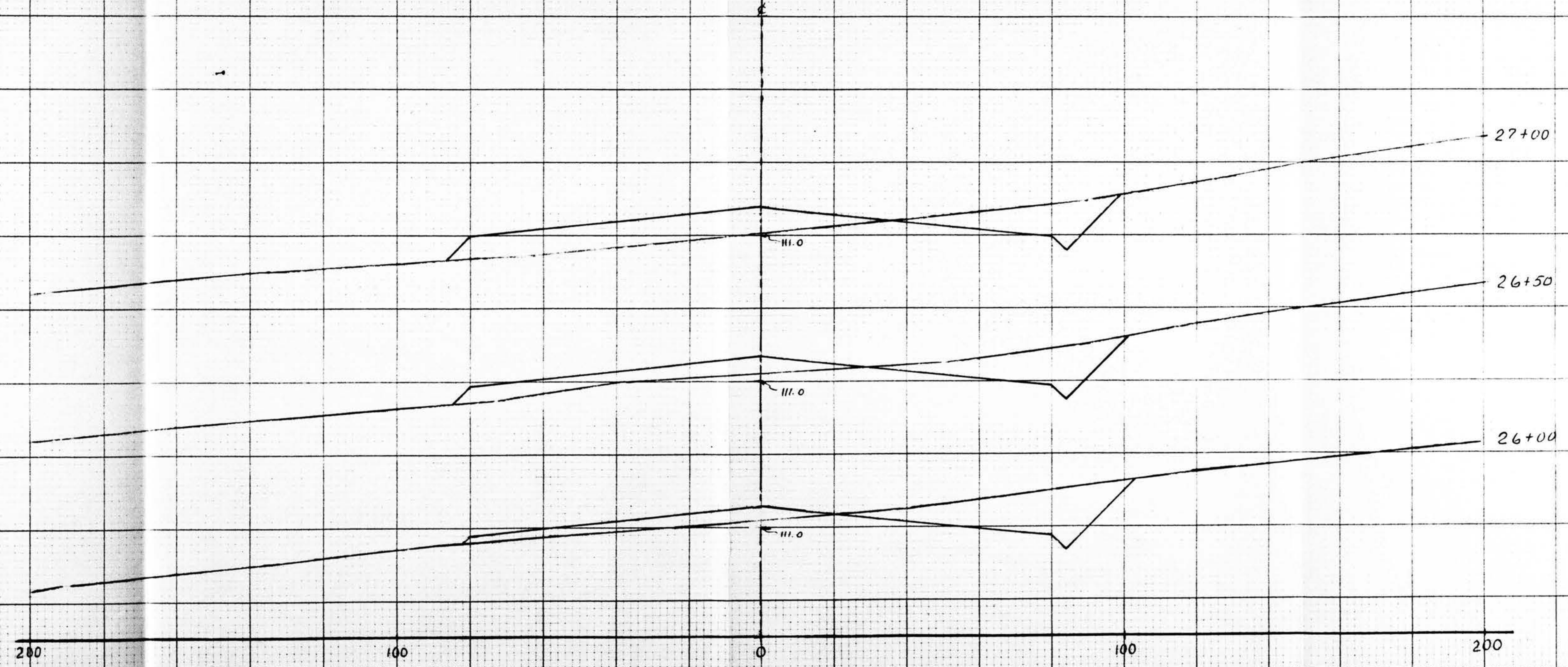
3



℄
106.0
13+50
13+00
106.0
12+50
106.0
Location of Culvert
12+00
106.0
Location of Culvert
200
100
0
100
200

Typical cross-sections of NE-SW instrument runway

4



℄
27+00
26+50
26+00
111.0
111.0
111.0
200
100
0
100
200

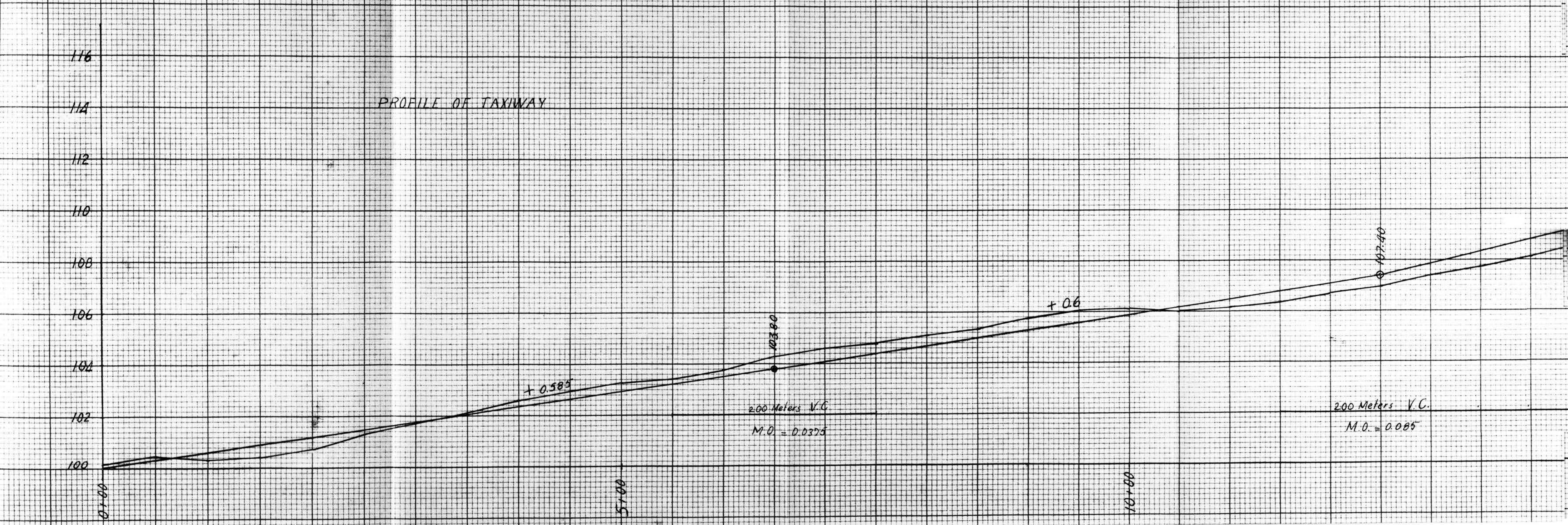

PROFILE OF TAXIWAY
116
114
112
110
108
106
104
102
100
0+00
5+00
10+00
+ 0.585
103.80
+ 0.6
107.40
200 Meters V.C.
M.O. = 0.0375
200 Meters V.C.
M.O. = 0.085

DIAGRAM III

Mass curve of NE-SW instrument runway

DIAGRAM IV

Proposed taxiway profile


+0.942
115.45
200 Meters V.C
M.O. = 0.235
+0.01
115.50
200 Meters V.C
M.O. = 0.0965
-0.385
111.00
Vertical Scale 1 inch = 2 Meters
Horizontal Scale 1 inch = 50 Meters
15+00
20+00
25+00
30+00
35+00

MASTER MAP-I

VILLAGE of ESENBOGA
NE-SW INSTRUMENT RUNWAY
5.4-26.64 KM (336-16.56 MIL) P.H.
OVER 27 KM (16.68 MIL) P.H.
NW
W 12.4
N
3.5
7.0
SW 10.3
40.7
NE
3.5
2.0
10.0
S
E
SE
ALL FIGURES INDICATE %
WIND ROSE
CALM %8
NO LOW VISIBILITY DATA AVAILABLE
Proposed Runway Pattern
Present Runway Pattern
GRAPHIC SCALE IN METERS
TURKISH STATE AIRWAYS
ESENBOGA AIRPORT
MASTER PLAN
SCALE 1:5000

BIBLIOGRAPHY

Glidden, Horace K., Law, Hervey F., Cowles, John E., Airports: Design Construction and Management. 1946

Sharp, H. Oakley; Shaw, G. Reed; Dunlop, John A; Airport Engineering. 1944.

Airports Flight Strips Construction by Public Roads Administration. June, 1943.

Duke, Donald; Airports and Airways - Cost, Operation and Maintenance. 1927.

Wood, John Walter; Airports - Some Elements of Design and Future Development. 1940.

Bruce, Arthur G., Highway Design and Construction. 1945.

Froesch, Charles; Prokosch, Walter; Airport Planning. 1946.

Airport Runway Evaluation in Canada by Highway Research Board. 1948.

Design Manual for Airport Pavements by Wire Reinforcement Institute, Inc.

Lewis, Harold MacLean; Planning the Modern City.

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