METAL TRACKS FOR AIRFIELDS

By S. K. Wadhawan

Defence Science Laboratory, New Delhi.

ABSTRACT

In this paper, the subject of metal tracks as means of rapid construction of runways during World War II has been reviewed. Brief description of some of the important light and heavy metal tracks has been given. Merits and demerits of both types of track are stated. Factors responsible for successful functioning of the track are enumerated and Pollit's account of the theory of track is presented. A summary of the post-war research on the field scale as carried out in U. K. is incorporated. Present trends obtaining in U.S.A. are indicated along with concluding remarks.

Introduction

Metal track and prefabricated bituminous surfacing (P.B.S.) are two distinct products of World War II that served as means of rapid construction of roads and runways. Metal track with or without P.B.S. was employed in the construction of advance airfields whereas P.B.S. apart from its use as runway material, was also greatly used for laying military roads in remote areas. Colquhoun and Brock [1] have fully described the work on P.B.S. in India during war. A similar description has been given by Grigson and Lee[2] on developments abroad. Besides, Grigson[3] has further extensively dealt with the subject of rapidly constructed airfields. This paper is a review of the development of the metal track since its advent in war and gives a brief account of the latest trends in the design of heavy track.

Origin of metal track

In the first World War, during Allenby's campaign in the Middle East, it was accidently discovered that ordinary wire netting when laid on sandy track facilitated the passage of vehicles. Thus the track was greatly employed as an aid to vehicular movement during 1914-1918. During World War II, British and American army engineers produced various designs namely Sommerfeld track, Pierced Steel Plank and Irving Grid. These were extensively used in U. K., Europe, Middle East, India and South-East Asia., In quickly changing situation during war, the use of these tracks was characterised by two novel features *i.e.*, the rapidity of their laying in active operational zones and the ease of their dismantling and carrying back in face of forced retreat.

Types of metal tracks

Generally speaking track surfacings can be classified into three main categories on the basis of their constructions--

(1) The membrane or mesh type, such as Sommerfeld track and the Square mesh track.

(2) The unit construction type examplified by P.S.P. (Pierced Steel Plank).

(3) The continuous structure type, such as Channel track.

Another classification results into such nomenclature as "light metal track" and "heavy metal track" merely owing to comparative difference in effective weight per square foot of steel from track to track.

Brief description of some of the important light and heavy metal tracks

Army, Sommerfeld, Square mesh, Bar-and-rod (light) and Channel are designated as light tracks and Bar-and-rod (heavy), P.S.P. and Irving Grid as heavy tracks. A brief description of important tracks follows [3,4]. Data regarding manufacturing details, physical properties and speed of laying is contained in the literature cited [4,5].

Sommerfeld track

This type of track was originally developed in the 1914—18 War as a road surfacing material and has been used extensively in England for fighter runways, taxi-tracks and hardstandings upon turfed soil. Under operational conditions it has not proved its worth.

Square Mesh track

This track is very much like welded mesh used in reinforced concrete. It is made in the form of panels or rolls but under active service conditions, panels have been proved to be superior to rolls.

Channel track

It is a comparatively light-weight and flexible steel surfacing, capable of rapid laying, for the construction of runways on soft or loose ground. It excels in larger distribution of load with a relatively small amount of material.

Heavy Bar and Rod track

This track has not been used on a large scale and is also difficult to fabricate. Load transference takes place from panel to panel.

Pierced Steel Plank track

This is the most important amongst all the tracks and has found far greater application than others. It is designed to withstand Tropical and Arctic conditions for all weights of aircraft and upon soils of various strengths. P.S.P. is more effective when weather is dry. During rainy season, the track becomes wet and muddy unless protected from rainfall by some means. It cannot be employed with ordinary P.B.S. as it punctures the hessian easily. This difficulty can be overcome by the use of 1″ sand-bitumen carpet or alternatively having a more stable base underneath. A 6-in course of cement stabilised soil has in many cases, a very similar construction value as a layer of P.S.P. and the weights of cement and P.S.P. required are almost exactly the same per unit area. Its manufacture is more rapid and simple than others. (Fig. 1.)

Irving Grid track

The Irving Grid type of track was designed by the Americans but it has been produced and used on a very modest scale. It is the heaviest track.

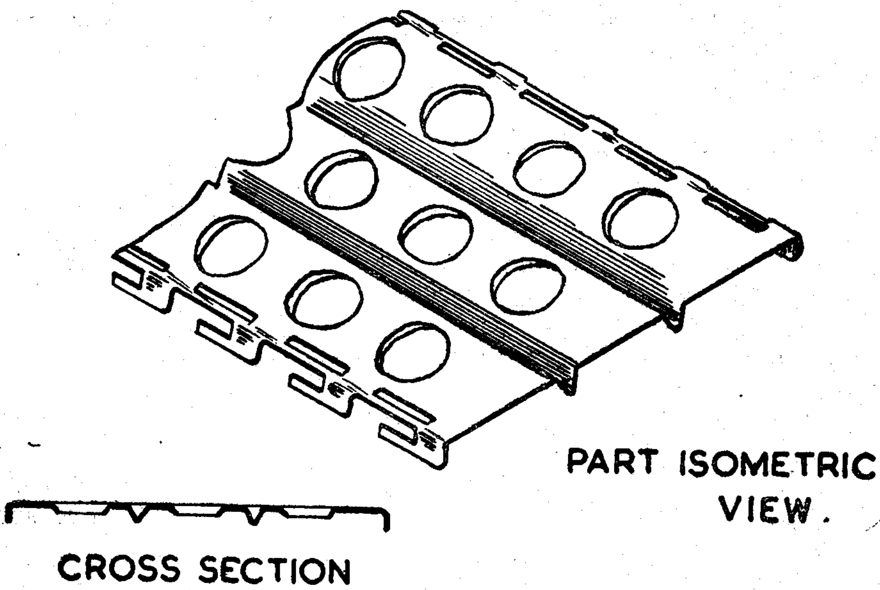

FIG. 1—Diagram of Pierced Steel Plank

Comparative study of metal tracks

During war, speed of construction of airfields is a vital factor. From the operational point of view, military airfields are seldom required to last long. Such airfields are termed forward or emergency airfields and are expected to operate for a period varying from one to six months. Both light and heavy metal track when laid have satisfied the requirements of military airfields.

All types of steel surfacings are designed for use under favourable climatic conditions with very little or modest preparation of base. They are suitable for permanent service only when laid on strong turf or well drained sandy and gravelly soils. Soils having low bearing capacity *i.e.*, heavy soils in Monsoon conditions are poor soils to be laid upon because these are in a highly dispersed state. Alluvials and laterites are however good. In general, soils having greater angle of internal friction *i.e.*, granular soils considerably add to the efficiency of the track.

Light metal track generally works well on soils of relatively high bearing capacity under arid to semi-arid areas. On soft soils, wheel loads cause large deflections with the result that the abrasive effect of traffic is promoted and increased. L.M.T. is not an all purpose track as it can exclusively be used by light fighters, fighter-bombers and light cargo aircraft having wheel loads not exceeding 15,000 lbs.

On the other hand heavy metal track is comparatively more useful than light metal track and under favourable conditions it may receive wheel loads upto 40,000 lbs. H.M.T. requires soils of good stability to be laid upon, on weak soils, a base course has to be provided.

Metal tracked airfields are essentially temporary airfields and there is therefore no point in comparing them with all weather permanent airfields having conventional type of pavement. However it is not without significance to mention that a runway of P.S.P. in conjunction with P.B.S. was in constant operational use at Changi airfield, Singapore from 1945—1949[6]. Its performance ranked excellently with permanent airfield.

Function of track

The function of track is to assist the soil to carry load by distributing a part of it outside the area of contact of the tyre. The proportion of the total load removed by the surfacing from the soil directly beneath the loaded area is termed the "fractional relief." The "fractional relief" varies from track to track and is dependent upon the extent of tension applied to the track and on soil and load conditions. The dispersal of load to surrounding areas adds to the bearing capacity of the soil.

In addition to the nature of soil which has a bearing on the satisfactory performance of the track, the efficientcy of metal tracks also depends on certain mechanical factors, *e.g.*, resistance to bending, resistance to tension, edge anchorage, degree of "keying" with the soil and finally the continuity of the track.

For small deformations of track and soil on airfields, the resistance to bending is the first requisite. As deformation increases, the resistance to tension, edge anchorage and "keying" assume importance. Therefore certain types of track need picketing and for some the edges have to be anchored. "keying" represents the state when there is sufficient cohesion in the soil to which metal can bite. On account of the "keying" action of the wire-netting which induces sheer stresses on the surface of the soil, the wire netting is weight by weight more effective than steel on plastic soils., The continuity of the track is responsible for rapidly spreading the pressures to surrounding areas. Ultimately the track should be robust enough to withstand breaking loads.

Theory of track

It is difficult to determine as to how track and soil react together under conditions of imposing load. The metal tracked pavement as a whole approaches flexible type of pavement in its behaviour, though it could be rigid also sometimes. The behaviour of versatile P.S.P. too, is not fully understood and a valid theory for its action in relieving loading effects on a subgrade is yet to be propounded[7]. Maclean[8] considers that the good performance of pierced steel plank is due to total plan area in contact with the ground being higher for this than for any other type of track. Based on an original method of Prandtl[9] evolved for estimating the bearing strength of plastic soils, Politt[10] has endeavoured to explain the functioning of track and soil together.

He considers an area of ground uncovered by metal track. On imposing an increasing load, failure of the soil will eventually take place by the soil failing in shear. The area directly under the load goes down and that surrounding the load goes up. (Fig. 2).

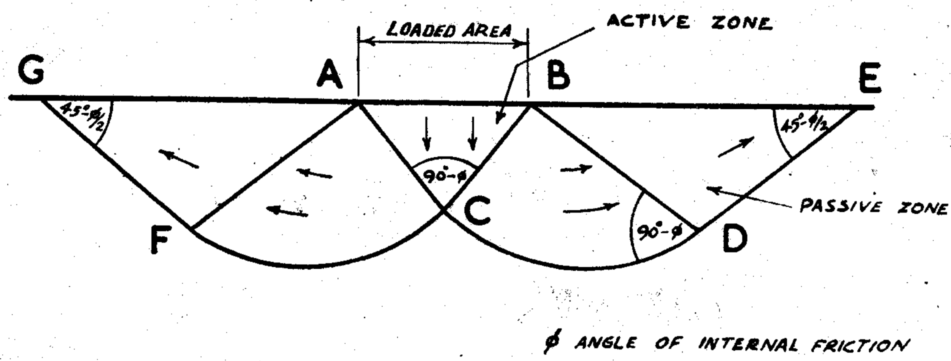

FIG 2—Showing likely failure of soil mass by shear beneath loaded area

1. The portion of soil bounded by △ABC moves vertically downward without deformation.

2. The areas ACF and BCD revolve outwards about A & B respectively. These areas are in a state of continued deformation by plastic flow.

3. The triangular areas AFG & BDE adjoining ACF & BCD push out bodily.

4. Shearing of the soil takes place along planes ACDE, BCFG and along AF & BD.

Next he considers an area of ground covered by track. When the track is picketed at both ends on a compact soil underlay, little or no tension takes place in the track. When the load is gradually increased, the soil is unable to resist and fails in shear exactly similarly as is the case with it on increasing the load without track. This failure however occurs only after the soil and track suffer deformation in several stages.

In the first stage, between the metal track and the soil the pressure underneath the loaded area is reduced and in the vicinity of the loaded area downward pressure is exerted by the metal track on the soil, the intensity and magnitude of this pressure fall off rapidly with the distance of the loaded area. Fig. 3.

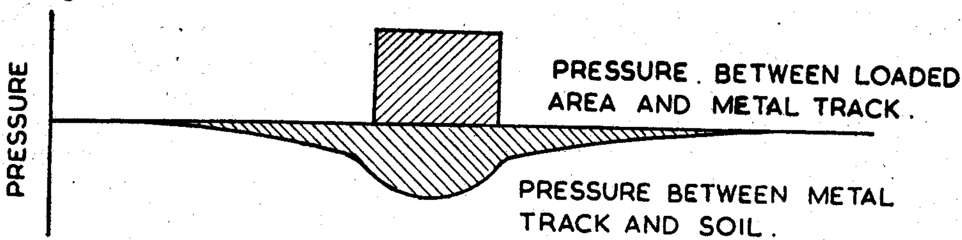

FIG 3—Pressure distribution in Soil-track System

(2) Next a minor deflection of the track due to bending results in the track exerting a downward pressure on the soil underlay. Fig. 4.

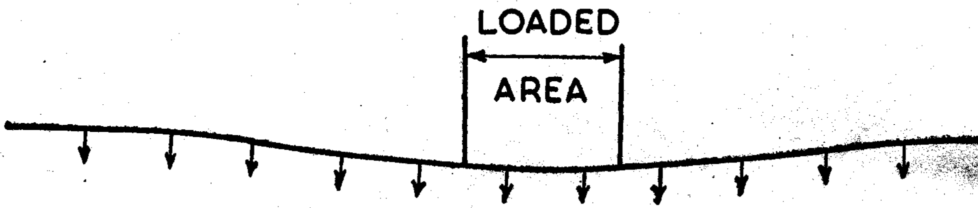

FIG 4—Deflection of track on bending

(3) When this deflection becomes large, tensional forces also operate. The track now exerts on the soil forces parallel to its surface as well as vertical forces. Fig. 5.

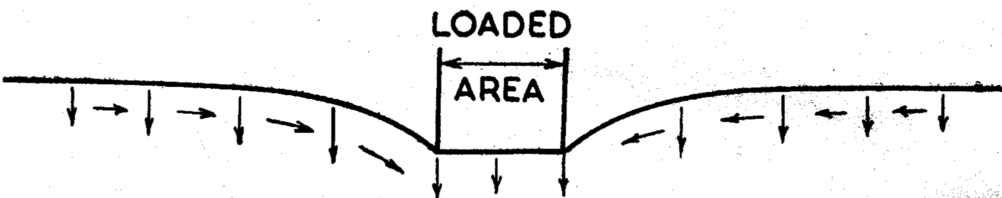

FIG 5—Deflection of track with bending and tension

It has been shown that the function of the track is to spread a part of the load to the surrounding areas thereby increasing the bearing capacity of the soil. This is equivalent to placing a surcharge pressure over the areas AG and BE. From Prandtl's theory it can be deduced that

$$p_1 = p_0 + \lambda p_2$$

where p_0=bearing capacity of the loaded strip with no surcharge.

p_1=bearing capacity of the loaded strip with surcharge.

p_2=surcharge pressure placed on areas AG and BE.

λ =number that varies with the angle of internal friction of the soil.

The relation between λ and ϕ the angle of internal friction is of immense applied value. Fig. 6.

Sand has a high angle of internal friction, whereas clay has a low angle of internal friction. Therefore for sandy soils for which value of ϕ is 30°—35°, corresponds to a value of 20—30. In case of clayey soils, ϕ = 10°—15° to which λ corresponds to a very low value of only 2. Thus on a sandy soil by applying a surcharge pressure of 10 lb/sq. ft, the bearing capacity of the loaded medium increases by approximately 300 lb/sq. For clay, the same surcharge pressure results in an increase of only 20 lb/sq. ft. in the bearing capacity. It follows that the track functions favourably on sandy soils than clayey soils.

Post-War Work in U.K.

Although metal tracks were extensively used during war and they proved their worth, very little fundamental research was carried out with a view to finding out their utility for permanent all weather roads or runways. Towards the cessation of hostilities and after, the Road Research Laboratory in U. K. carried out full scale traffic trials in the field with the object of comparing performances of both types of track under identical conditions[11].

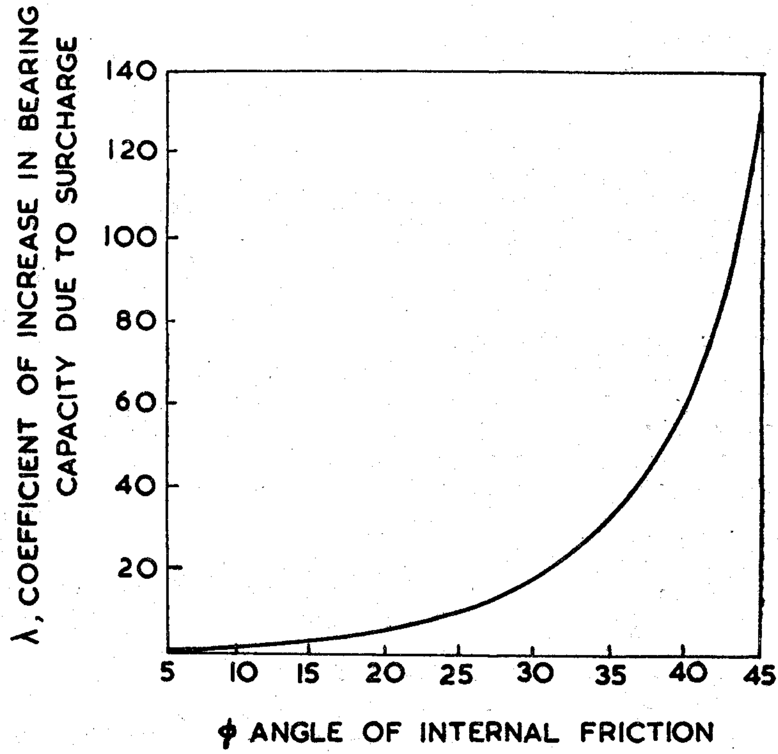

FIG 6—Effect of surcharge on bearing capacity of soil

From these tests emerged the following important conclusions:—

(1) Heavier tracks were more effective than lighter tracks.

(2) There is a definite quantity of steel to be used as an underlay.

(3) More steel should be placed transversely than longitudinally in the structural design of the track.

(3) Small diameter bars closely spaced are more effective than large diameter bars widely spaced.

Present trends

It has been mentioned earlier that Pierced steel plank had been widely used during World War II and had proved to be most useful track. It is still in use and is probably the only track on which considerable research has taken place in recent years. American engineers have produced many new types of P.S.P.[12]. The P.S.P. at present in use there, is very much similar to its old counter-part and is designated M 6. The only major deviation has been the introduction of end connectors which help to distribute the applied load in a longitudinal direction from one plank to another. In the design of

M 6, a number of teeth are projected on the underside of the track which cannot be used in conjunction with P.B.S. as it is easily torn by the teeth. This defect is avoided in a later design known as M. 8 which is considerably stronger and heavier than M. 6. Its weight is reported to be 7·3 lb. per sq. ft. as against 5·4 of M 6.

A runway 8000 × 150 ft. complete with a return taxiway, operational readiness platforms and hardstandings for two squadrons of fighter aircraft might require some 5,000 tons of P. S. P. (M 6.)

Progress along these lines has revealed the presence of some kind of light plastic or fibre glass mat and prototypes of this kind have already been produced in U. S. A. though details are lacking [12].

Conclusion

From a study of the foregoing, it is evident that the metal tracks were manufactured and utilised on a mass scale during World War II and proved highly successful. In the invasion of North West Europe as many as 80 airfields were surfaced with metal tracks alone. Since then, times have greatly changed and rapid strides in aviation have brought forth big increase in all up weights and tyre pressures of aircrafts, posing numerous problems for the construction of sturdy runways.

The changeover from piston-engined aircraft to jet aircraft is a postwar development which has a bearing on runway design. At present all up weights of 200,000 lb and tyre pressures 300 lbs. per square inch appear to be the standards to be attained in aircraft manufacture but such trargets as 500,000-lb aircraft, 400-lb per square inch tyre pressures, vertical take offs and rocket propulsion in the coming years should not be ruled out [13]. This means that we are confronted with the task of designing and constructing longer, thicker and stronger runways than has been possible uptil now. Experience gained so far shows that double slab concrete pavements or prestressed concrete pavements may be able to withstand sustained loads of the magnitudes indicated above. Viewed from this aspect, there is little or no future for the light metal track but heavy metal track, especially P.S.P. will continue to be deployed in some form or other. Moreover, in contrast to concrete pavement, P. S. P. has successfully withstood the heat and blast of jet aircraft; and fuel spillage does not appear to produce any harmful effect on it[14].

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