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Behaviour of Drift Sand and Method of Dealing with it

BY

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" The wind blows where and how she lists " and the behaviour of such a loose substance as drift sand volatilized under the effects of such a wild force of nature as high wind, will most naturally, appear to defy all calculations and laws. We know, however, that nature, even in its wildest forms, has a method, no matter how rough and rugged it may appear ; and by an observation of the behaviour of sand we can surely look forward to results of practical value.

Proper drift sand consists of extremely fine grains which get finer every day by the action of wind. These particles, however small, are miniature stones of varying shapes ; some are nearly circular and roll along in high wind or jump along the surface of sand. Others are more or less flat and the progress of these is of a sliding nature. These particles have no clay as a binder and no cohesion. They have no stability like the proverbial " stairs of sand " to allow any thing to grow on them, proper " rolling stones gathering no moss." In fact they work as the biggest scourge known to vegitable kingdom and wipe out its hardiest forms.

The drift sand varies in its origin :—

(*i*) There is the drift sand of marine origin. At points of the shores where there are gently sloping beaches and the wave action is not so violent, the fine sand held in suspension is deposited. These particles, belong to the type of drift-sand grains and are susceptible to winds of even a moderate intensity. The prevailing winds, blowing in-shore, in the absence of any natural or artificial barrier, carry them in-land in the form of dunes. They cause wide-spread devastation by burying and so destroying all vegitation encountered in their progress.

(*ii*) There is also the inland drift sand from barren hills which are devoid of all vegitation. The stone is gradually pulverised to infinitely small particles by the action of wind and weather and is in time converted into drift sand of quality above described.

(*iii*) The inlaned sand-drifts are also formed out of over-cultivation of sandy soil which is not recouped with clay or silt from canal irrigation or any other source.

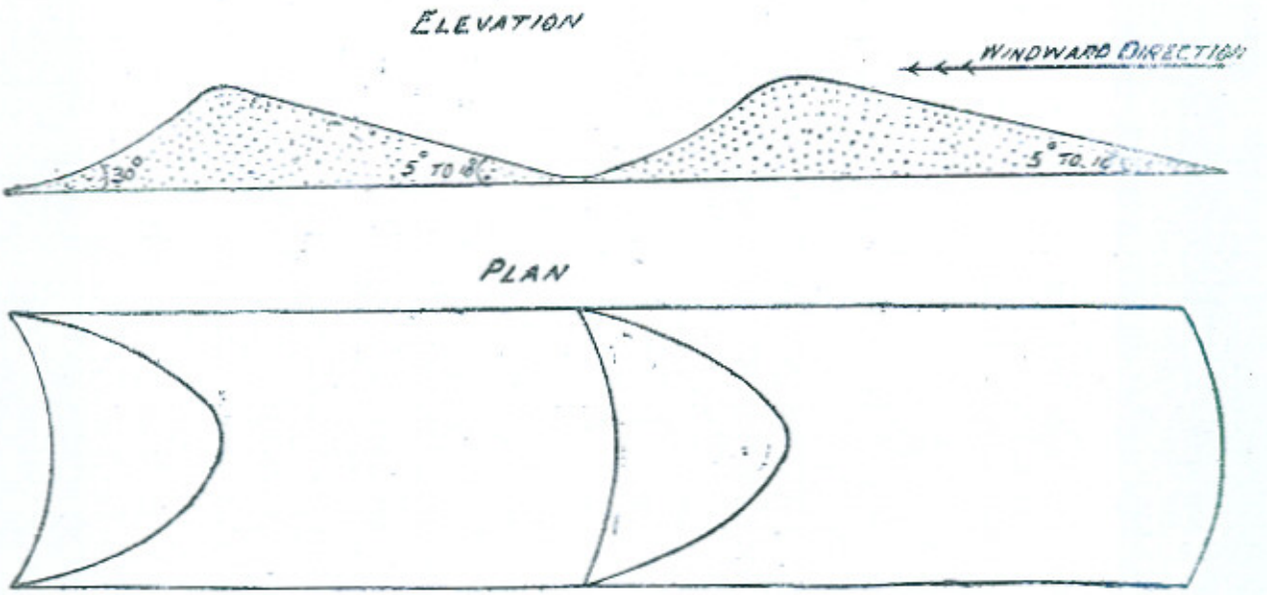
(*iv*) The changed courses of rivers when dried up also act as reservoirs of drift sand besides the quarries in sandy soils.

The drift sand, whatever its origin, starts moving in the direction of the prevailing winds and receives accretions during its progress owing to its erosive action on the soil over which it passes and which it also gradually converts into sand drift, working like a salt mine in the famous Persion Proverb, "Any thing that goes into a salt mine becomes salt." The drift sand then shapes itself into dunes which become bigger in size on meeting a barrier or any feature preventing the progress of simple blowing, *i.e.*, when the rolling or sliding particles of sand can not get over steep obstacle at the velocity of wind impelling them. Any obstacle works as a sand trap and serves as a neucleus round which the big dunes are formed. These dunes extend in wave formation and give any one the appearance of the sea in storm. The mirage can give the picture a finishing touch except, of course, the ship of the desert, coming on the scene per-chance may destroy the delusion.

The sand dunes are located transversely to the direction of the impelling wind and this fact can serve independently as a guide to find out the direction of the prevailing wind. These dunes are formed either in banks of considerable length or as isolated sand hills of a peculiar shape.

If we study a sand hill we find that its lee-ward slope is usually about 30° *i.e.*, a gradient of about 1 in 2. The wind-ward slope, however, is very much easier and varies, as a rule, from 5° to 10°. It may be steeper according to the strength of the wind, quality of sand, and the sand reserves behind the dunes, being steepest when the supply fails at the back. If you examine an isolated dune you will find it crescent shaped with its gentler sloped convexity on the wind-ward side and steep concavity on the lee-ward side. The reason is not far to seek. The obstruction of the sand drift acts as a wind screen and the sand drops more abruptly in the still pocket immediately behind the hill while it is carried a longer distance at the ends where the atmosphere is not so still, this giving the ends an elongated appearance resulting in the form of a crescent shaped dune. The still air behind the hill, working like a standing wave, in the atmosphere is also responsible for the steep slope on the lee-ward side while the gentler slope on the wind-ward side is formed suiting the motion of the sand particles rolling in high wind, in the face of an obstruction. They naturally form a slope by which they can roll across the obstruction at the usual velocity of the impelling winds.

If we have a high obstruction in the form of a wall or sarkanda fence, as artificial sand drift with a gentler slope on the wind-ward side will be formed. This characteristic affords us one of the best methods, of a lasting nature (to be dealt with later) of checking the on-ward flow of sand at its source or anywhere else, provided the portion behind it can be 'fixed' or stabilized by means of clay admixture and suitable grass being planted to be of any lasting value. In India sarkanda has been found to be most suitable. This, of course, is a measure of country wide



application and cannot suit a mere narrow strip of land that we have to deal with in case of Railways in this country.

The sand dunes under the effect of impelling winds travel forward and their motion resolves itself into a virtual rolling motion. As described above the sand particles from the top and sides are carried due to the high velocity of wind up the gentler wind-ward slope and after leaving the crest as they meet the still air pocket or the standing wave in atmosphere on the lee-ward side, and having also reached the minimum of velocity at the crest, they drop suddenly. By this transference of sand from the wind-ward to the lee-ward side the sand dune rolls bodily along at rates, varying considerably according to the location of obstructions, humidity of atmosphere, force and frequency of winds, size and the height of dunes, and the quality of sand itself. The motion forward of the sand dune during the whole year will depend among other factors, on frequency and intensity of the winds and their prevailing direction throughout the year.

The movement of any isolated dune during an individual sand storm will also depend on all these factors and should be determined experimentally by those who have to deal with this trouble, by means of stakes, fixed for reference. Very high sand dunes move very slowly indeed ; 100′ high sand dunes have been recorded to move at the rate of 50′ a year, whereas I have seen a dune of 1′ height moving at the rate of 2′ per hour, and such a dune in fact constitutes a greater danger as it may be unnoticed and will move easily 50 to 60 feet in a storm of moderate intensity and duration. The motion forward bodily of the sand drifts is the most important factor to know about their behaviour ; a factor, which results in a dangerous blocking of the line by the sand dunes getting astride of the track burying it under several feet of sand for any length and resulting in derailments, heavy detentions and untold

misery to the travelling public. Apart from this motion of dunes bodily a certain proportion of sand is blown by the high winds beyond the shelters of the dunes, and is driven across the intervening space to the next dune or any obstruction ; thus if the sand blowing from one side of the line meets with a sand dune or any other obstruction on the other side it will fill up the intervening space between the track and the obstruction ; and result in ultimate blocking of the line.

Apart from the two conditions, *i.e.* (*i*) a sand drift getting astride of the track by its forward motion or (*ii*) sand filling between a dune or obstruction on the lee-ward side of the track, it is not to be feared as a rule, that track will be blocked to a dangerous extent by merely blowing of sand against the obstruction of rails. This fact lessens the value of various chute devices or mechanical blowers to keep the track clear, apart from their draw back of blowing away packing of sleeper. It would be enough in such a track to use B. H. rails giving an opening for blowing of sand and to prevent too much accumulation of sand in between rails. This fact also is responsible for the valuable results obtained by levelling down of sand or by raising a track above the level of dunes.

Having had an insight into the behaviour of the shifting sands under various conditions it is now proposed to discuss the methods adopted from time to time to deal with the evil. These measures fall into 2 main heads :—

(1) Arresting the on-slaught of the sand dunes on to the railway track with a view to minimise the danger of derailments and detentions to trains and nuisance to the travelling public in the narrow strip of the land belonging to the railway.

(2) The eradicate the evil from the country as a whole by a co-ordinated effort between various departments like ; Forests, Irrigation, Roads and Railways.

The main head (1) has a distinct draw back since the most ingenious methods adopted by the Railway Engineers, of a real permanent value, are bound to be so expensive as to be exhorbitant. In case of the semi-permanent measures, inspite of fairly heavy expenditure in the beginning the problem will not be solved permanently and will still require recurring expenses. Other methods of purely temporary nature only play about with sand in the narrow strip of land belonging to the Railways and involve very high recurring expenditure.

To the first category of methods which offer prospects of solving the problem once and for all belong the two following measures, contemplated by the Germans in their African Colonies, though hardly put into practice :—

(*i*) The erection of concrete roofed shedding over the section of the line liable to encroachment by sand so that the track would be practically in a sand proof tunnel, over which the sea of sand would roll on beating its fury in vain. This, inspite of the initial heavy expenditure involved,

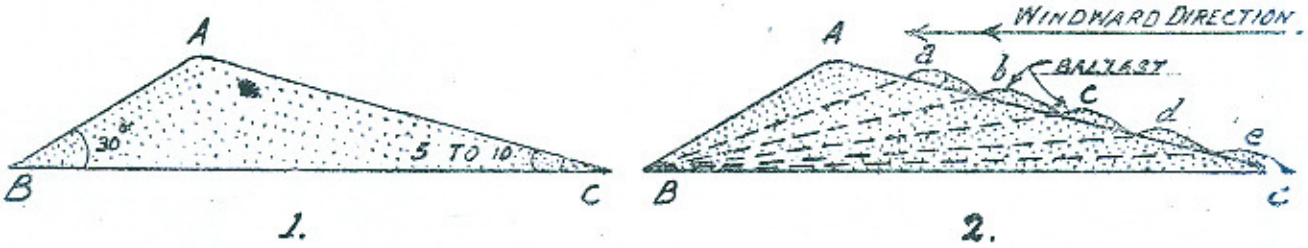
would prove a cheaper method in the long run in a real desert and will do away entirely with any recurring expenditure ;

(*ii*) The raising of the line on a trestle formation to allow the sand to pass freely below. This method is also of a permanent value and unless the sand dunes are very high requiring the line on trestles to be raised to such heights as to subject it to severe wind pressure during high winds. In the categories of the methods of a permanent value and those that have been tried with any success on this railway are the following :—

(*i*) Raising of the line where possible from point of view of grades, etc., above the level of the highest sand hills in the locality. We have seen that it is the sand dunes moving bodily along getting astride of the track to their full amplitudes that are a real menace to the trains. It follows, therefore, that when the track and the dunes are at the same level there is very little obstruction and the sand blows freely across without actually blocking the line to any dangerous extent. This method, which was tried, on Kundian-Mianwali section of this Railway ; has proved successful. The trouble simply ceased to exist on the reaches which were so treated.

(*ii*) Levelling down the sand dunes by means of an appliance like levelling tractor or bull-dozer. This method is particularly useful when there are low places also and the problem should be almost solved if the sand could be led into such depressions ; ultimately giving the surroundings a level surface which is easily amenable to wind action. The sand particles will thus continue to cross the track without blocking it. In Kundian Sub-Division we used bullocks which dragged a country made scraper to level down the sand dunes. The modern bull-dozer can certainly be used more economically and with far better results.

(*iii*) Again, since sand drift, as stated above, cannot be checked at its source due to our being confined to the narrow strip of the railway land the crossing of the track by sand drifts became a necessary evil. Our operations were mainly directed with a view to regulating its passage across the line in such a manner that it did not get astride of the track in the form of dunes. With this object each sand drift was taken in hand as soon as it arrived within 50 or 60 yards of the track. The wind-ward side of the dunes was ' fixed ' and the sand prevented from blowing by a layer of stone ballast, spread over it up to a little distance of its crest. Since the travel of sand particles from the wind-ward side was thus stopped and those that were blown away from the uncovered crest were not allowed to be replaced the steep lee-ward slope became gradually flatter. The strips of the covering were successively removed by men down the wind-ward side exposing the new crest to the wind ; the sand dune became flatter and flatter and more exposed to wind action until the whole hill was blown across the line by degrees. The sketch below will help to explain the method.



(1) shows the section of a natural dune progressing by gradual transference of sand from 'C' over 'A' to 'B'. The slope AB is about 30° and that of AC usually from 5 to 10°.

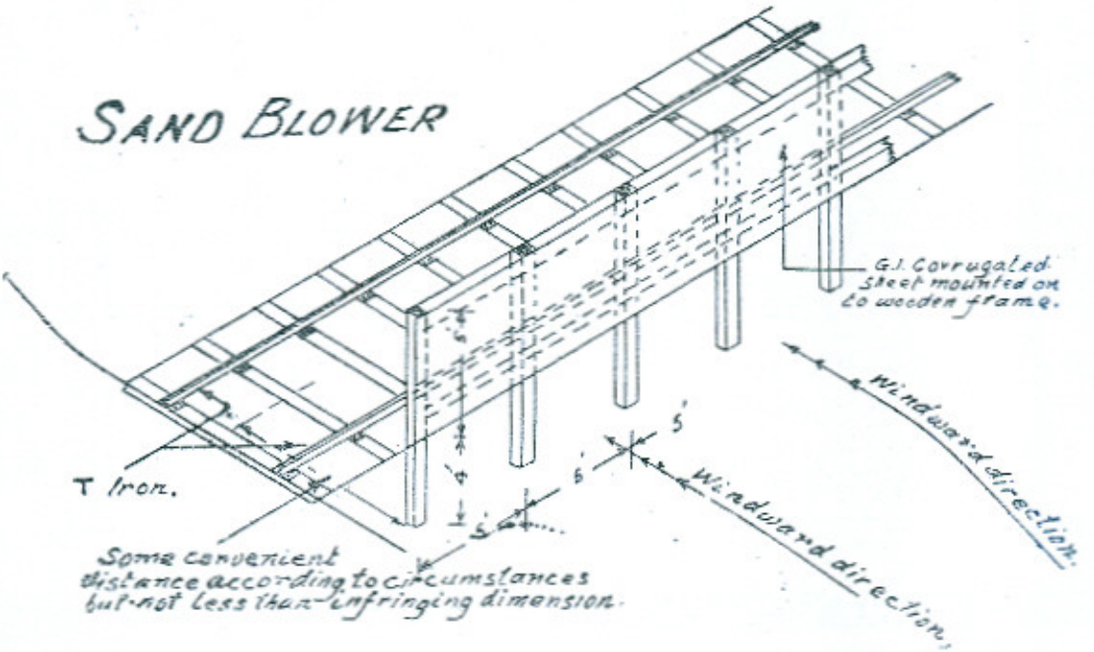
(2) shows the section of similar dune with strips of covering aa, ab, bc, cd, and de & eC. As these are successively removed the slope BA gradually assumes the form Ba, Bb, Bc, Bd and Be, and the sections ABa, ABb, Abc etc., are blown away until at length the dune is destroyed. In case it was found difficult and more expensive to fix the wind-ward side with binding material like stone ballast and also the labour was comparatively cheaper the sand from drift was carried by means of Jhambars (lidless wooden boxes with handles) being filled with sand from the wind-ward side far out on the lee-ward side of track and thrown to the winds to be blown farther and farther away from the track and using any low ground if available for dumping sand.

Track Clearance. Although apart from the sand dune coming bodily on to the track the sand deposit in between the rails will not, ordinarily, be dangerous but as stated above it may become dangerous in certain conditions, particularly by filling back, if there are drifts close on the lee-ward side. Besides if this sand accumulation is not cleared it will rust away the rails particularly with moisture. Further harmful effect of the sand particles getting into the bearing surfaces of the axles of the rolling stock and moving parts of engines can hardly be over rated. Their life is shortened and sometimes it may lead to dangerous results. To make matters worse stone ballast which would have prevented sand from blowing by passing trains is not used in the track, for if this is used for packing sleepers, it simply goes down irretrievably. Sand is, therefore, normally used for packing underneath the sleepers and is found to serve the purpose fairly well. A layer of stone ballast is, however, spread over the track as a blinding material to prevent sand from blowing. This blinding layer, however, gets buried under fresh accumulation of sand which defeats its object; and for this and other reasons given above the track has to be kept clear of sand. Several methods have been adopted to achieve this object :—

(*i*) **Manual Labour.** The patrol men, employed for this purpose, clear the track by means of showels throwing it to the lee-ward side of the prevailing wind, if any blowing at the time, so as to blow it far away from the track. If there is no wind at the time sand accumulation is filled in the Jhambars and carried off towards the lee-ward side of

the track and dumped far away, preferably in low places. Care should be taken that the blinding layer of stone ballast is not carried with it. This, in fact, should be properly replaced if disturbed.

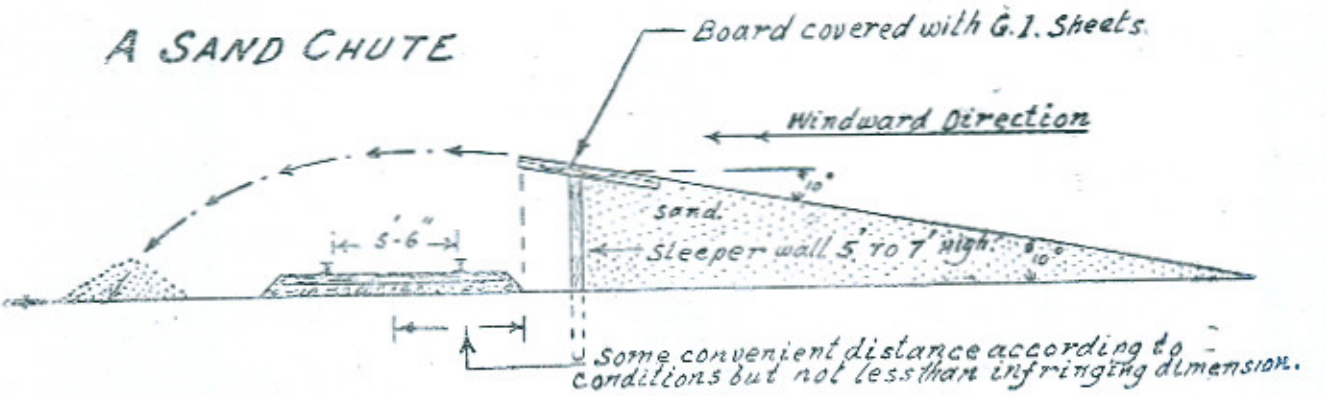
(*ii*) Among the mechanical appliances used for keeping the track clear of sand the best known is what is termed ' Wind Accelerator ' or a mechanical blower.



This consists of old sleepers or other timber being used as fences upon which a double width of galvanised sheets is nailed, leaving a space between the lower edge of the G. I. sheet and the ground, which varies according to the local conditions from $1\frac{1}{2}'$ to $3'$; the whole resembling a school blackboard in appearance. This is fixed as close to the track as possible (the actual suitable distance being determined by experiments in mild storm). A forced draught is produced in the opening at the bottom which intensifies the action of the prevailing wind at the time, and the sand, instead of pilling up against the fences, is blown underneath at a great velocity across the railway line and sweeps over clear of the track on to the lee-ward. It really cleared the track of all sand but did more. It, very often, scoured and blew out the packing from underneath the sleepers, which as stated above also consists of sand. Another draw-back of this method was that very often the sand accumulated close by on the lee-ward side, particularly with a very low velocity of wind. This would be again a source of nuisance when the wind changed its direction. This method also is mentioned very briefly in the ' Austral News ' of July, 1944, and an extract was very kindly shown to me by the C. E. N., N. W. Rly. This is marked in the ' News as a novel method, though from the point of view of North Western Railway Engineers it is very old, and in fact, it has now become obsolete for the draw-backs mentioned above and

because local labour besides being cheaper in this country helps intelligently in piloting train in case of emergency. Besides their local knowledge and experience is of yoeman's service to the engineers-in-charge.

A SAND CHUTE



(*iii*) Another interesting and ingenious method which has been tried on this Railway with the same object in view is as follows :—

It consisted of sleeper wall topped with a G. I. sheet sloping up towards the track at 5° to 10° to the ground. This was fixed at places which had extra high sand hills. The height of the sleeper walls was fixed according to the height of the sand dunes and was higher than the average sand dunes in the locality. In the beginning it acted as a screen against blowing sand and gave great relief from sand accumulation in the track. It worked like a sand trap till reserve sand accumulated behind it in the form of an artificial dune to the full height of the sleeper wall at the usual angle of 5° to 10°. After this stage the sand continued to blow over the smooth and firm inclined planes of the G. I. sheets and left it in the form of a trajectile and following its parabolic path according to the velocity of the wind would fall clear of the track on to the other side. The distance of the wall from the track would vary according to the local conditions and was fixed as near to the track as possible, so as not only to allow greater relief in the beginning by longer time taken in the accumulation of reserve sand but also enabling the storm of even a low velocity to carry the particles of sand clear of the track. This method brought great relief in the beginning by completely blocking the sand and particularly in allowing the track to remain extra clean during a sand storm. This method however, had a great draw-back for the sand that went on the lee-ward side of the track often formed a sand hill on that side and when the wind changed its direction once again we had the tables turned against us. Besides this method actually results in creating great hillocks of sand very close to the track without actually 'fixing or stabilising' them by growth of any grass and in the long run did more harm than good.

This brings us next to the country-wide measure of eradicating the evil or what may be called the Reclamation of the Sand Drifts. This is done in the following steps :—

(*i*) The first object to be aimed at for this purpose is to cut off the supply of sand from its source by the creation of an unsurmountable artificial barrier and fixing the barrier itself with plantation.

(*ii*) Fixing the drift sand behind the protection of the barrier and gradually extending the operations to the whole of the affected area.

The first step is best achieved by creating on artificial dune, and this is as mentioned above based on the fact that shifting sand accumulates against any obstruction in its path until an easy slope is formed to wind-ward which will allow of its passing over the obstacle, since a stronger impulse is necessary than in the case of a flat surface. The obstacle employed is usually a wooden barrier. In some European countries the barrier has been now superseded by the use of Marran grass. In most of the affected parts of India sarkanda has proved quite efficatious for the purpose. In countries, however, where these will not grow due to climatic reasons but other bushes are available for use, the wooden wattled barrier has still to be adopted. Where bush is not available, sand bags may have to be used.

Wherever practicable the barrier should run at right angles to the direction of the prevailing wind, though it may be necessary to follow certain features of the country or to follow the trend of a curving coast line in the case of coastal barrier where the sand supply is of a marine origin.

The barrier consists of verticle poles about 6½′ long driven about 2′ in sand, made from the bushes, locally available. These are fixed at about 2½′ apart, depending upon the branch wood which is then reved in between them for a height of 3½′ thus leaving a few inches of each upright bare from top as otherwise the top layers of branch wood is blown off in a storm. A barrier of this description on gently sloping ground is quickly buried by the sand it arrests. As soon as this occurs, a second barrier is erected immediately above it and this process is repeated until the dune attains a height which renders the wind-ward slope sufficiently steep to prevent the sand grains from rolling to its summit save in exceptionally strong wind while particles blown from the top are caught in the eddy formed in the lee of the sand dune and deposited within the area sheltered by it.

This method of creating a dune naturally involves the employment of large quantities of poles and branch wood which once in position cannot be recovered but is cheapest when such material is available in the vicinity of the scene of operation. When, however, this is not the case wooden palisade resembling fencing picket may be substituted. Such palisades may be conveniently 6½′ long and are driven into sand, pointed end down wards and broad side facing the wind. When the sand has accumulated to within 3 or 4 inch of the top they are pulled up another 3½′ so as to form a fresh barrier. The intervals between the palisades allow sufficient sand to pass through for the level of sand at the back, necessary for the maintenance of the stability of the palisade

while they are not so wide as to destroy the shelter, necessary for the creation of the dune.

Sometime it is possibie to find a wave of sand, approximately in the position where it is required to form the artificial dune and it is certainly a saving of both time and material to erect a barrier on such a dune instead of having to raise it from the ground level. When the artificial dune has reached the required height, which may be as much as 40'. in big schemes, very little sand will be reaching its summit even during very strong winds. The top should be rounded off so as to permit of the whole being planted and thus stabilised. This is done by erecting a second wattled fence a few yards behind and parallel to the original barrier. The rounded top is then fixed and planted by suitable plants selected by experience for the locality. As stated above Marran grass in European countries and sarkanda in India have been tried with success though of course planting these is an art in itself, requiring lot of experience. It is done in a season when there is moisture and the seedlings may have to be held in position by trungers or stones, and mixed with clay, silt, town refuse or any such material to help the growth of the grass. When the artificial dune has been thus stabilised and planted the blockade of the ingress of sand from its source may be said to have been accomplished, by sand itself. The next step is to take in hand the reclamation of sand to the lee-ward side of the barrier. For this purpose, again, the sand is temporarily fixed by means of brush wood or any other covering agency such as stone, clay, etc., and seed of shrubs and trees adapted for the locality, sown in due season, specially when there is moisture present. This, although a country-wide measure has been used to protect the narrow strip of land belonging to the railway. It was not given sufficient trial in Kundian for lack of space in the railway limit and was, presumably, chucked off on account of threatening sand hills of great height that formed close to the track. There was also lack of clay or such binding material enabling planting of sarkanda, besides the lack of moisture. At Kundian I always thought that the problem could be solved if there were a summer crop to cover the sand. There was a winter crop of grams and wheat but that did not help since there was no trouble in winter. In fact by an over cultivation, as stated above it made matters worse since the clay was not recouped by canal irrigation.

From Kundian I was posted to Sukkur where my chief trouble was to face the floods in summer. What a boon, I thought, it would be if this surplus water, causing such a havoc down below, could be utilised higher up in irrigating irid wastes of the Mianwali District thus harnessing such a wild force of nature as a devastating flood and banishing no less an evil as drift sand by giving it a cover of silt and better still of crops. This, I always considered the real permanent measure to eradicate the evil at Kundian. Irrigation incidently helping the railways while filling its own coffers with untold revenues into the bargain. The Thal project, I understand, is now coming and

the problem would be solved. The Forest Department can then follow suit and change the aspect altogether.

In the absence of canal irrigation and in extremely dry climate like that of Kundian, Hydroscopic agents like calcium chloride always appeared to me to offer as a substitute provided it was mixed with clay as a binder since it is bound to help the fixing of sand and promote the growth of grass, etc., by the moisture it absorbs from the atmosphere.

This is not known in my experience to have been used in fixing off drift sand but is, however, worth trying. I understand the Alkaline Chemical Works at Khewra—a place not far away from Kundian—is producing enormous amount of calcium chloride as a bye-product. This is not required by them and can be had for the asking and an experiment carried out at Kundian.