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Use of Alberta Bituminous Sands for Surfacing of Highways

BY

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USE OF ALBERTA BITUMINOUS SAND FOR SURFACING OF HIGHWAYS[1]

INTRODUCTION

The Mines Branch investigation of the bituminous sands of northern Alberta was continued by the writer during the field season of 1926. Paul Schmidt acted as field assistant and G. P. Connell was in charge of laboratory analyses and physical determinations. Both discharged their duties in an efficient and satisfactory manner.

Work undertaken constituted a logical sequence in the program planned some years ago when the investigation of the bituminous sands was initiated. In the following pages reference is made to that portion of the field program of 1926 dealing with paving and construction.

PAVING AND CONSTRUCTION

During the latter part of 1925, it was decided to surface with McMurray bituminous sand approximately three miles of highway in Jasper Park at Jasper, Alberta. Subsequently in February, 1926, it was suggested by the Commissioner, Canadian National Parks, that this initial surfacing be undertaken with the co-operation of the Mines Branch, Department of Mines.

The section of highway surfaced leads from the town of Jasper, Alberta, to Jasper Lodge, a summer tourist hotel operated by the Canadian National Railway System. Traffic during the summer months may be described as fairly heavy. In 1926 it was equivalent to upwards of five hundred motor cars per day in addition to a fleet of 2-ton motor trucks operated by the Parks Branch. The road has been re-surfaced and gravelled at least three times during the past three years, and is now equivalent to a fairly well-compacted macadam. Sub-soil consists of river wash comprising boulders, gravel, and sand. Curves are numerous and sharp. With the completion of the proposed highway between Edmonton and Jasper, marked increase in motor traffic may be anticipated.

The proposed paving involved: (*a*) selection of an area from which suitable bituminous sand could be secured; (*b*) opening up of a quarry with mining and shipping of required tonnage of bituminous sand; (*c*) designing and operating a commercial mixer suitable for the manipulation of bituminous sand; and (*d*) laying the surface mixture in place. The first three divisions of the above work were referred to the writer.

[1] For detailed reference to the bituminous sand deposit of northern Alberta see Mines Branch Report No. 632 (1926).

SELECTION OF AN AREA FROM WHICH A SUITABLE CLASS OF BITUMINOUS SAND COULD BE SECURED

As indicated clearly by the writer in various published articles and reports, the character of Alberta bituminous sand varies widely throughout the McMurray area. At certain points the material is highly banded with impurities and apparently is worthless for paving purposes; at other points the aggregate is coarse or fine according to local conditions under which the sand was originally deposited. From point to point throughout the entire area, percentage of associated bitumen varies widely. Overburden to be removed constitutes an important factor.

In 1924 the writer suggested that a limited area underlain by bituminous sand (parts of secs. 13 and 14, tp. 89, R. 9, W. of 4th mer., east of Clearwater river) be placed under reserve for Departmental purposes, and for the use of any private investigators who might wish to undertake the erection of semi-commercial plants in connexion with experimental work. After due consideration it was decided, in spite of obvious transportation difficulties, to excavate bituminous sand required for the Jasper highway from this reserved area.

As a preliminary step a limited amount of prospecting was undertaken by the use of 2-inch asphalt augers. The following abridged analyses (Table I) of samples secured in this manner, indicate the general character of the aggregate, and the degree of impregnation of the bituminous sand. It may be noted that there was marked evidence of slipping in the bed of bituminous sand excavated (Plate IA), with infiltration of water and subsequent leaching out of bitumen along all slip planes. This condition is fully described in Mines Branch Report No. 632, page 54.

TABLE I

Abridged Analyses of Samples of Bituminous Sand Taken in Quarry at McMurray

Sample No.	Per cent moisture, as received	Passing mesh						Retained on	Per cent associated bitumen	
		200	100	80	40	20	10	10	Dry basis	As-received
1	3·9	1·3	6·8	14·7	69·1	7·4	0·7	......	12·6	12·1
2	1·4	1·6	8·6	15·0	66·4	7·4	1·0	......	15·1	14·9
3	3·7	1·3	5·7	6·6	65·8	20·5	0·1	......	12·4	11·9
4	2·8	1·9	7·1	8·3	65·6	16·1	0·9	......	12·7	12·3
5	1·1	1·7	5·6	6·8	40·2	34·7	10·3	0·7	11·4	11·3
6	9·0	1·9	8·9	11·9	45·6	27·0	4·4	0·2	14·2	14·1
7	3·7	0·7	7·4	16·3	72·4	2·9	0·3	......	14·2	13·7
8	2·4	1·4	8·3	16·5	64·1	7·6	1·9	0·2	14·7	14·3
9	4·3	1·8	7·8	12·7	63·3	11·4	2·5	0·5	11·7	11·2
10	2·8	1·3	7·1	15·3	64·8	9·7	1·6	0·2	12·8	12·4
11	8·6	2·0	6·6	11·4	73·8	5·7	0·5	......	13·3	12·2
12	1·6	2·3	7·3	16·3	63·1	9·1	1·7	0·2	14·4	14·2
13	1·5	1·5	5·3	7·7	75·7	9·6	0·2	......	14·0	13·8
14	2·0	1·9	5·7	9·2	65·9	15·0	2·2	0·1	13·2	12·9
15	1·9	1·6	5·0	7·3	68·1	15·5	2·1	0·2	12·5	12·3
16	1·7	1·7	6·0	7·9	77·0	7·2	0·1	trace	13·6	13·4
17	1·2	3·0	6·1	9·4	54·7	23·8	2·8	0·2	11·6	11·5
18	1·8	2·9	8·1	12·0	67·5	8·6	0·7	0·2	14·2	14·0
19	0·6	1·5	4·0	5·5	68·6	17·6	2·8	0·1	15·9	15·8

Analyses given in Table I indicate an unbalanced aggregate. Previous experience had shown, however,[1] that when combined with suitable clean aggregate, a satisfactory wearing surface could be produced. Accordingly preparations were made to undertake the necessary preliminary excavation.

QUARRYING AND SHIPPING BITUMINOUS SAND

In order to uncover the bituminous sand, it was necessary to remove a certain amount of the overburden which consisted of a variable thickness of boulder clay underlain by from 2 to 4 feet of sand and soft sandstone. From 1 to 4 inches of the upper surface of the bituminous sand itself was weathered and partly leached out. The average thickness of overburden removed was approximately 12 feet.

Having removed the forest growth, a light winch was installed and belted to a gasoline tractor. This was used to operate a No. 1 slip scraper dragged by lead and tail wire cables (½-inch diameter). This simple and inexpensive equipment was easily installed and worked smoothly and efficiently.

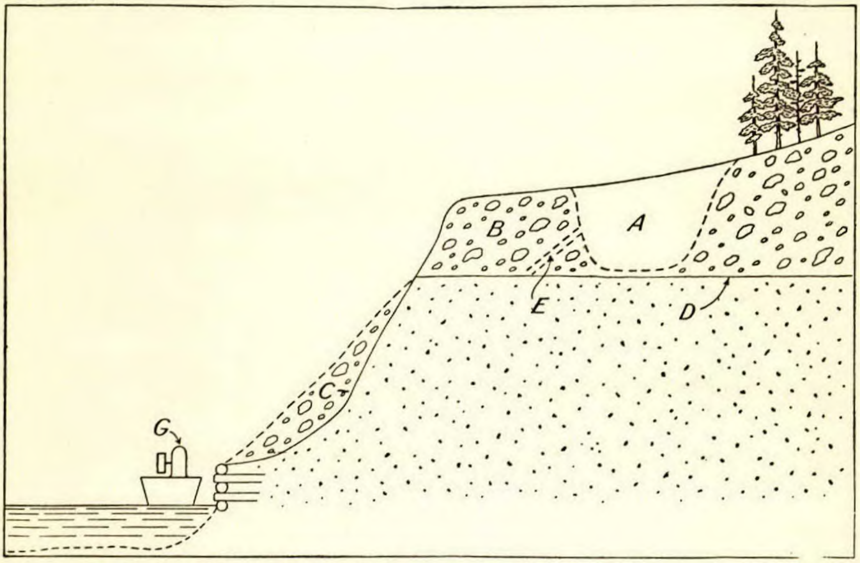

Figure 1. Section illustrating method adopted at McMurray for removal of overburden. A, cut made by slip scraper; B, overburden; C, overburden broken down by blasting; D, upper surface of bituminous sand; E, 6-inch holes for blasting; G, pump belted to tractor and mounted on scow, (capacity, 500 gallons per minute, 50 pounds pressure, 1½-inch nozzle).

Waste material from scraper cut, A, (Figure 1) was disposed of in an adjacent ravine. Material indicated as B, was then drilled by means of a 6-inch, post-hole auger, the holes loaded with No. 1 black blasting powder, tamped with heated bituminous sand, and fired in groups by a battery. The blasted material indicated as C, was then readily hydraulicked into Clearwater river by the use of a pump G, belted to the gasoline tractor and mounted on a small scow moored to the shore (Plate IB).

[1] Mines Branch, Dept. of Mines, Canada, Report No. 632, p. 81 (1926).

The bituminous sand was drilled by means of asphalt-augers and broken down by the use of No. 1 black blasting powder. When the excavated lumps of bituminous sand were too large to be handled conveniently, they were again drilled by means of a small breast auger and further reduced by light charges of 40 per cent dynamite. When necessary the lumps were further broken by the use of sledges.

The lumps of bituminous sand were then wheeled on barrows to a loading-chute discharging directly onto decked scows. These were pushed up Clearwater river by power boat a distance of approximately one mile, transferred to a small mine car, hauled by cable and winch up a trestle, 160 feet long, and discharged, by means of a loading-chute, onto the deck of standard railway flat cars. In spite of the above somewhat cumbersome method of transportation and loading, cost of bituminous sand per ton delivered on railway cars did not exceed the writer's estimated cost of $3 per ton. Scow transport and loading at railway siding did not operate to capacity, since the mining personnel was limited to four men. By increasing the output at the quarry, the cost of bituminous sand, f.o.b. cars, can be materially reduced.

From the past season's operations it appears that, apart from cost of removal of overburden, the following force of men will mine at the Clearwater pit, and deliver on railway cars, Waterways, 60 tons of bituminous sand per 10 hours.

One foreman in charge of quarry at $3 per day; 2 drillers, 2 men breaking rock, 2 men loading scows, 1 blacksmith, 2 men on scows, 1 man operating trestle mine car, 1 man on trestle, 3 men unloading scows, 1 cook, all at $2.50 per day; total costs being as follows:—

Wages, 16 men	$40 50
Board at 75 cents per man per day	12 00
Explosives, gasoline, and oil	8 00
Supervision, etc.	5 00
	$65 50
Contingencies (10 per cent)	6 50
	$72 00

Introduction of labour-saving equipment would materially increase efficiency.

HEATING AND MIXING BITUMINOUS SAND[1]

As a preliminary to undertaking the proposed paving program at Jasper, Alberta, the writer spent a few days in studying various rock asphalt plants in Texas and in California. The following remarks are based, in part, on observations made during the above period.

For many years, natural rock asphalts, including bituminous sand, bituminous sandstone, and bituminous limestone, have been used in the construction of various types of wearing surfaces in the United States. In connexion with this construction, various types of heated mixers have been designed and successfully operated in Utah, Kentucky,[2] Oklahoma, Texas, Alabama, and California.

[1] See also Mines Branch Report No. 632, Chapter III (1926).
[2] At present Kentucky rock asphalt is laid cold.

The record of early development of rock asphalt paving was, however, marred by many failures in practically every field in the United States. Such failures not only entailed the loss of large sums of money but, for a time, seriously prejudiced the public against the use of the natural material. Failure was due to various causes which are now well recognized. Among these are included lack of uniformity in the materials quarried and shipped, and carelessness or lack of skill during subsequent manipulation. To the use of unsuitable rock asphalt, and to overheating, may be attributed 90 per cent of failures. The result of overheating—burning the flux, when used, and even the bitumen in the rock asphalt itself—is seen in ravelling, and to a lesser extent in shoving. To-day, responsible producers of rock asphalt[1] exercise the greatest care in ensuring that only suitable material is shipped, and, as a rule, in spite of keen competition, mixing plants are operated by paving contractors in a careful, intelligent, and conscientious manner. One important rock asphalt producer in Texas will sell his product only to responsible paving contractors. When there appears to be uncertainty as to the character of the paving work that is being done, the shipper insists on being represented—at the paving contractor's expense—by one of his own inspectors. As a result, in the United States, the undoubted value of suitable rock asphalts is more and more being recognized and their commercial application extended. It will be most unfortunate—and indeed inexcusable—should those who attempt the introduction of Alberta bituminous sand as a paving material fail to profit by the mistakes that marked the early history of the use of rock asphalt in the United States. It is not the writer's intention to attempt to compare natural rock asphalts with refinery products. It may, however, be pointed out that, during mixing and heating, the naturally distilled bitumen in rock asphalt is subjected to a much lower temperature than that which prevails during the production of petroleum residuum.

It appears clear that the naturally distilled bitumen associated with certain varieties of bituminous sand has undoubted merit. Thus a quantity of bituminous sand, said to have been mined at Carpinteria in 1877, was apparently still as full of "life" immediately below the surface when observed by the writer in 1926, as when originally excavated.

Design and Operation of Mixer

In the United States, heated mixers of large capacity (portable, semi-portable, and stationary plants) for the manipulation of rock asphalt, are of two general types, viz., those internally heated and those externally heated. In Texas and Alabama internally heated mixers are in general use for the treatment of bituminous limestone; elsewhere externally heated mixers have been generally adopted. Smaller, portable, internally heated mixers for the manipulation of bituminous concrete, sheet asphalt, and asphalt mastic have also been manufactured for a number of years by various companies. A typical example is the No. 12 Koehring hot

[1] It appears that in Texas the Uvalde Rock Asphalt Company has been largely responsible for the pioneer work in placing rock asphalt on a satisfactory commercial basis. Today, this company is prominently identified with the mining of rock asphalt, and with paving operations in which this material is used.

mixer (Plate II A). It is claimed that under ordinary conditions, sand, gravel, or stone which does not contain an unusual amount of moisture, can be heated to 400° F. in such a mixer in from three to four minutes. Preheated asphalt cement, if used, is then poured or pumped from the measuring tank into the mixing drum, and combines with the hot aggregate in about one minute.

Selection of the type of heated mixer should be governed to some extent by the character of the bitumen associated with the rock asphalt, and the ease with which it breaks down when heated. It should also be governed by the length of time required to heat a unit batch of material. Owing to the higher percentage of light oils usually associated with the bitumen, Alberta and California bituminous sands require a much longer period of heating than bituminous limestone. Consequently, the cubic capacity of the mixing-drum should be considered as an important factor in designing equipment for the manipulation of bituminous sand. It is not clear as yet whether the internally heated mixers or the externally heated mixers will ultimately be found best adapted to the commercial manipulation of Alberta bituminous sand. The writer considers that the problem is of sufficient importance to fully justify a series of comparative tests with each type of equipment.

Externally Heated Mixers[1]

Of the externally heated mixers, drums locally known as " torpedoes " or " torpedo guns " have been used most generally. Examples of portable and semi-portable units are illustrated in Plates IIB and IIIA and the general arrangement is shown in Figure 2. In this figure, A is a sprocket $8\frac{1}{2}$ inches in diameter, B is a clutch control lever, C are 6-inch bearings, D is a 24- by 9-inch pulley, E is a $4\frac{1}{2}$- by $5\frac{1}{4}$-inch gear, F is a 5-inch bearing, G is a drive gear, 54-inch diameter (the screw conveyer feeds the charged materials through centre of this gear), H is a 25-inch sprocket, J is a screw conveyer, of 1-inch metal and with a 12-inch pitch on shaft, 2 inches square and with 4-inch rounded ends, L is a stack, M is a semi-circular housing of $\frac{1}{16}$-inch metal secured together by semi-circular angles $\frac{1}{4}$ by $1\frac{1}{2}$ inches. The housing is further stiffened by the use of $\frac{5}{8}$-inch rods. The stack is 10 or 12 feet high and 10 or 12 inches in diameter. N is a removable plate for closing discharge end of torpedo. It is secured to the neck of the torpedo at three points by means of clamps, with a slotted rod and key to lock it into place. This appears to be a somewhat clumsy arrangement and could doubtless be improved. O is the torpedo tube, P is a spiral, flanged-plate, screw conveyer 6 inches in diameter and having a pitch of 12 inches. The metal is $\frac{1}{4}$-inch thick and spaces are left between the shell of the tube and the conveyer blades. Each turn of the screw is secured by four light brackets ($1\frac{1}{2}$ by $\frac{1}{2}$ inch), Q is the charging-platform, R is the support for two travellers which carry the discharge end of the torpedo tube. These travellers have special oiling devices. S are the metal sheets enclosing the fire-box. They are of cast iron, 1 inch thick, with $2\frac{3}{4}$-inch webs at

[1] U. S. Patents, 393,616 (1888); 415,167 (1889); 464,642 (1891); 467,302 (1892); 470,159 (1892); 498,957 (1893); 502,211 (1893).

bottom, top, and sides. Spikes (3-inch centres) are cast on the inner face in order to take up expansion and contraction. The plates are secured by ⅝-inch draw rods and bolts. Heating is accomplished by means of gas or oil, the ends of burners being inserted at two or more points on each side and inclined downward, so that flame strikes the ground and is deflected upward. The foundation is usually of concrete.

As originally operated by the Santa Barbara Paving and Grading Co. (E. P. Stevens, Manager, Summerland, Cal.), maintenance charges of "torpedo" mixers were practically prohibitive. Later, on the suggestion

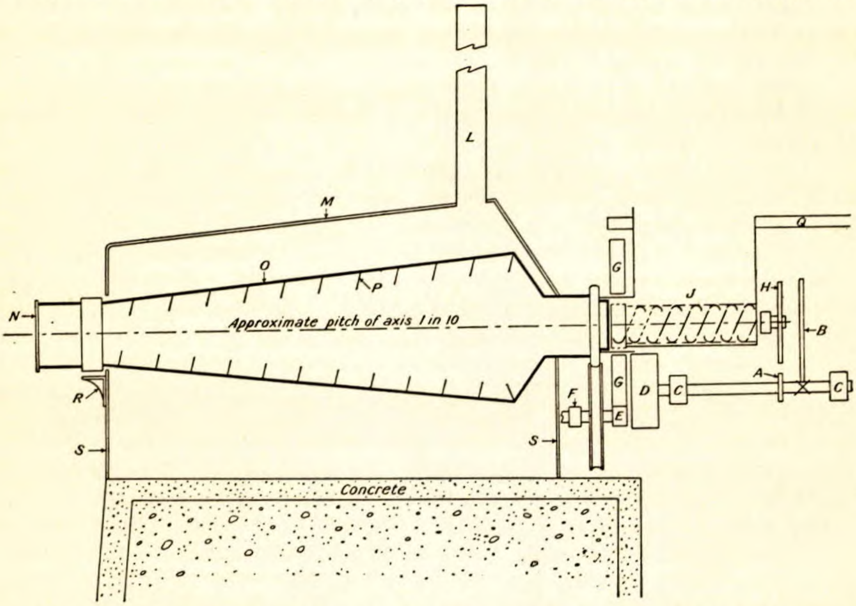

Figure 2. General section illustrating construction of externally heated "torpedo" mixer.

of Mr. George Westwick, of the Westwick Iron Works, Santa Barbara, Cal., the position of drive and trunnion bands relative to the axis of the drum was altered, and feed mechanism was added. "Torpedoes" are usually erected in pairs in order to ensure continuous output should it be necessary to stop one of the drums for any reason. Capacity of individual drums should be such as will furnish one truck-load of paving mixture per batch.

In commencing operations, it is customary to ignite the burner nearest to the charging end first; 500 to 600 pounds of the charge is then introduced in order to ensure lubrication of the inner surface of the drum, and the remaining burners lighted. If temperature and speed of drums—usually 6 to 7 r.p.m.—are properly regulated, "balling" and coking of charged materials can be reduced to a minimum. Carelessness will, however, result in the formation of coke from 1 to 1½ inches thick. This will not only injure—or even ruin—the batch, and clog the mixing-blades, but may also seriously injure the "torpedo" itself. An intelligent operator will acquire efficiency in handling equipment of this type in 3 or 4 days' time.

Cold bituminous sand and clean aggregate are brought in wheelbarrows to the charging-hopper and are moved by the screw conveyer, J, into the mixing-drum. With the larger type of "torpedoes," a two-drum batch consists of approximately 4 cubic yards of mixture, and to bring this to a temperature of 350° F. usually requires a period of from 18 to 20 minutes. When heating and mixing are completed, a discharge gate, N, is opened and the batch discharged. Exact time of heating is largely determined by observation of the colour of the gases given off, and results are thus dependent on the experience, skill, and judgment of the operator. In California it is usually considered that a batch is "cooked" when escaping oil vapours change from a light bluish white to a deep yellow. While the last batch is being drawn, gases remaining in the drum are blown out by steam. Failure to observe this precaution frequently results in an explosion accompanied by serious results. It is to this feature that the term "torpedo gun" may be attributed.

It might appear that there is danger of cracking the bitumen by bringing it into direct contact with the heated inner surface of the drum, but the large mass of cool aggregate, which is usually introduced at the same time as the bituminous sand, probably tends to offset such action. Certainly surface mixtures heated in "torpedoes" are free from cracks which might be traced to undue heating. It thus appears that the use of "torpedo" mixers does not injure the quality of the bituminous sand mixture. It may be noted that it is not considered good practice to preheat clean rock aggregate before introducing the bituminous sand, since this tends to cause coking on the hot surfaces of the clean rock. Should it be necessary to stop a drum while being heated, the lower surface of the drum continues to absorb heat from the furnace while the upper surface tends to cool off. This results in warping and distortion of the shell, and constitutes an unfavourable feature.

Construction of "torpedo" mixers is comparatively simple, and the cost of a 2-drum unit should not exceed $4,500. It is stated that the capacity of such a unit, when Carpinteria bituminous sand is used, is approximately 120 cubic yards of paving mixture per 10 hours. At present (March, 1927), "torpedo" mixers are being operated near Carpinteria, Cal., by A. Sattler, and near Santa Cruz, Cal., by John de Bruynkops of San Francisco.

Plants of the above type have been constructed by the Westwick Iron Works, Santa Barbara, Cal., and by the Schneider Engineering Works, Columbia Engineering Works, and Bay City Iron Works, San Francisco, Cal. Practically all patterns required for the construction of "torpedoes" are available at the Westwick Iron Works, Santa Barbara, Cal.

Internally Heated Mixers

The essential features of an internally heated mixer plant, usually but not always, are two revolving drums and either one or two externally placed combustion chambers, locally known as "targets." The inner periphery of each drum is equipped with a series of flights of mixing-blades, somewhat similar to those used in certain types of concrete mixers. Apparently the introduction of internally heated equipment may be attributed to the late F. O. Blake who secured the first patent (U. S. Patent 924,132) on June 8, 1909. Prior to this date, Mr. Blake had invented a device for re-heating asphalt wearing surfaces for the purpose of making repairs, and the equipment described in Patent 924,132 was merely a new and materially modified application of the principle involved in the re-heating equipment. In Texas, F. O. Brown, Sr., and F. O. Brown, Jr., (1416 South Harwood St., Dallas), have been prominently identified with the development and operation of internally heated mixing equipment.

An interesting example of a single-drum unit is that designed in 1926 by W. M. Jagoe, President, Jagoe Construction Company, Dallas, Texas. This plant[1] —which together with boiler and other auxiliary equipment is mounted on a standard flat car—was placed in commission in June, 1926. It is said that operation has been satisfactory. The principal features are indicated diagrammatically in Fgure 3. In this figure, A is a

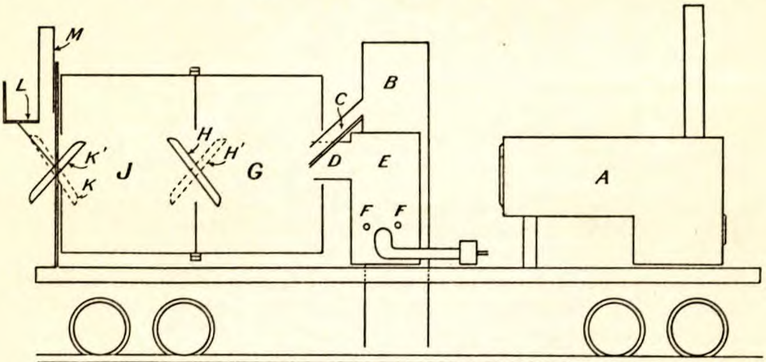

Figure 3. Single-drum, internally heated mixing plant, Jagoe Construction Company, Dallas, Texas.

steam boiler, B an elevator (lifting crushed rock asphalt from the crusher), and C the chute leading from elevator to the mixing-drum. This chute—the bottom of which is water jacketted—passes diagonally across the end of hot air flue D, from oil-fired combustion chamber E. This combustion chamber is equipped with a 6-inch blower and two oil burners F.F.

In operation, approximately 3 tons of crushed rock asphalt is charged into compartment G of the mixing-drum and heated for a period of approximately $1\frac{1}{2}$ minutes. Chute H is then reversed into position H′ by means of a suitable arm and lever, and the batch passes into compartment J, a new charge being at once introduced into compartment G. In compartment J the necessary quantity of hot flux is introduced, and after a short period, chute K is reversed into position K′ and the batch discharged into the street truck. A platform, L, is provided for the drum attendant. Smoke from the drum is carried away by a flue, M, equipped with a steam jet to provide increased draft.

[1] Constructed by the Mosher Steel and Machinery Co., Dallas, Texas.

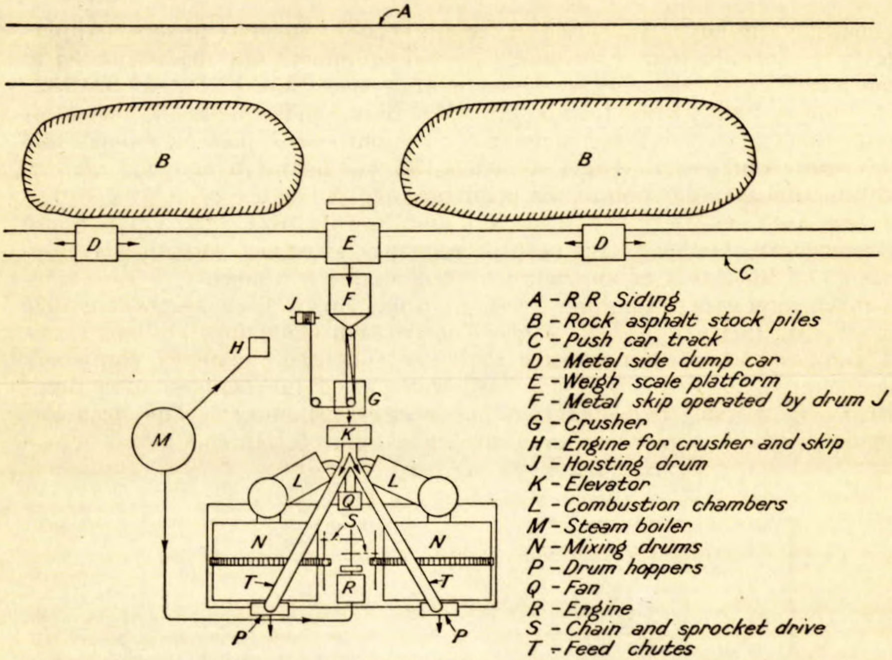

Figure 4. Diagram illustrating installation of internally heated mixing plant at Fort Worth, Texas. (General Construction Company.)

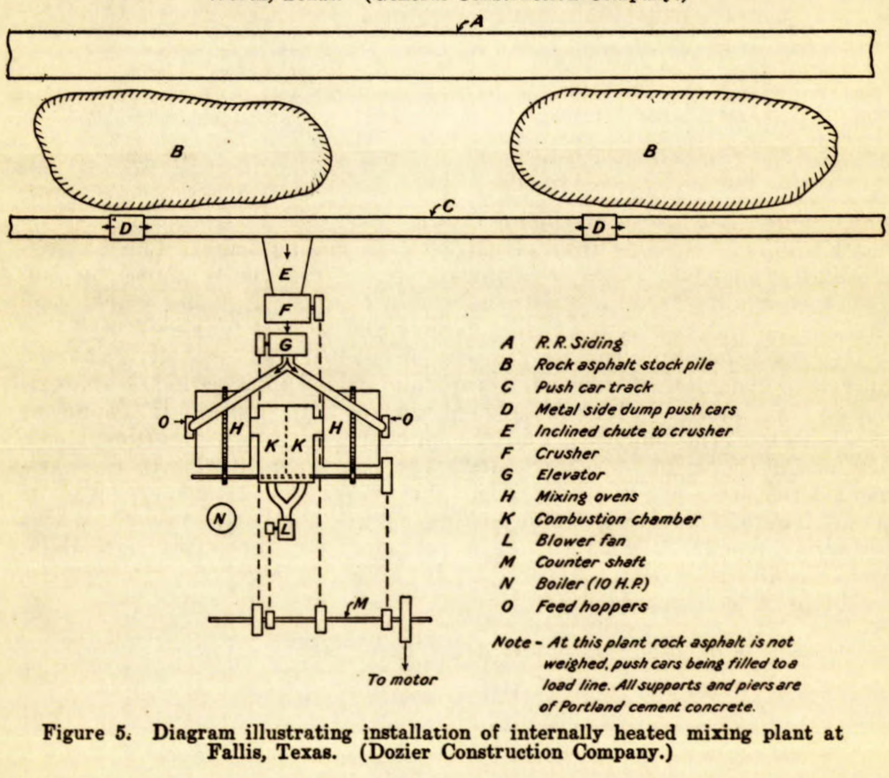

Figure 5. Diagram illustrating installation of internally heated mixing plant at Fallis, Texas. (Dozier Construction Company.)

For a number of years, 2-drum units (Plates IVA and IVB) have been used for the heating and mixing of bituminous limestone (chiefly Uvalde rock asphalt) by various companies in Texas, Alabama, and Louisiana.[1] The general arrangement of two representative plants is diagrammatically illustrated in Figures 4 and 5. Power to operate the drums is transmitted in a variety of ways. One of the most efficient installations noted by the writer, comprises a motor, reduction gear, and a silent chain drive which transmits power direct to the line shaft operating the drums.

However, the use of internally heated mixers had not been previously attempted for the manipulation of bituminous sand. Probable periods of heating were thus unknown, as well as the effect that the somewhat high temperatures might have on the soft bitumen associated with the bituminous sand. On the other hand, the admitted success that had followed the adoption of internally heated mixers elsewhere, encouraged the writer to attempt the use of similar methods in connexion with the manipulation of Alberta bituminous sand. Two discarded concrete mixing-drums were therefore secured, and steps taken to assemble the necessary auxiliary equipment. This work was commenced on July 17.

Valuable time was lost in determining the internal design and dimensions of the combustion chamber, design and length of hot air flues, and in securing oil burners, and a suitable class of fuel oil. It was then found that the original mixing- and lifting-blades in the drums themselves were entirely too light, and it was necessary to replace these with much heavier ones. It was also necessary to design and install a new type of feed hopper and discharge chute. Finally, it was necessary to alter drive gears in order to secure proper speed of rotation, and to add clutches to the main drive shaft. The plant was completed on September 4, shipped to Jasper on September 8, and erected in approximately six working days. Cost of materials and labour in assembling the plant for shipment was approximately $2,000.

The writer then proceeded to McMurray, erected the necessary loading-trestles, supervised the first shipment of bituminous sand, and returned to Jasper on September 18. It was then found that the clean aggregate, (crushed limestone and gravel), which had been secured, carried too high a percentage of fine material, and it was necessary to secure and install a revolving rock-screen. This installation was completed on October 1, and the first batch of mixture turned out on October 6. However, unseasonably wet weather and frost caused delays which further retarded progress. A considerable part of the wearing surface was laid on a subgrade which was distinctly damp.

The plant (Plate IIIB and Figure 6) was operated for 16½ working days, and during this period a total of approximately 500 tons of surface mixture was produced and sent to the road. As might be expected in the operation of a new type of plant—especially when assembled largely from

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[1] Green, Roy M.: Bituminous Pavement Investigations in Certain Texas Cities, Bull. 24, Texas Engineering Experiment Station (1921).
Clark, G. H.: Rock Asphalts of Alabama, and their use in Paving, Special Report No. 13, Geol. Survey of Alabama (1925).
McNew, J. T. L.: A Study of the Fluxing of the Bitumen contained in Texas Limestone Rock Asphalt, Bull. 31, Texas Engineering Experimental Station (1926).

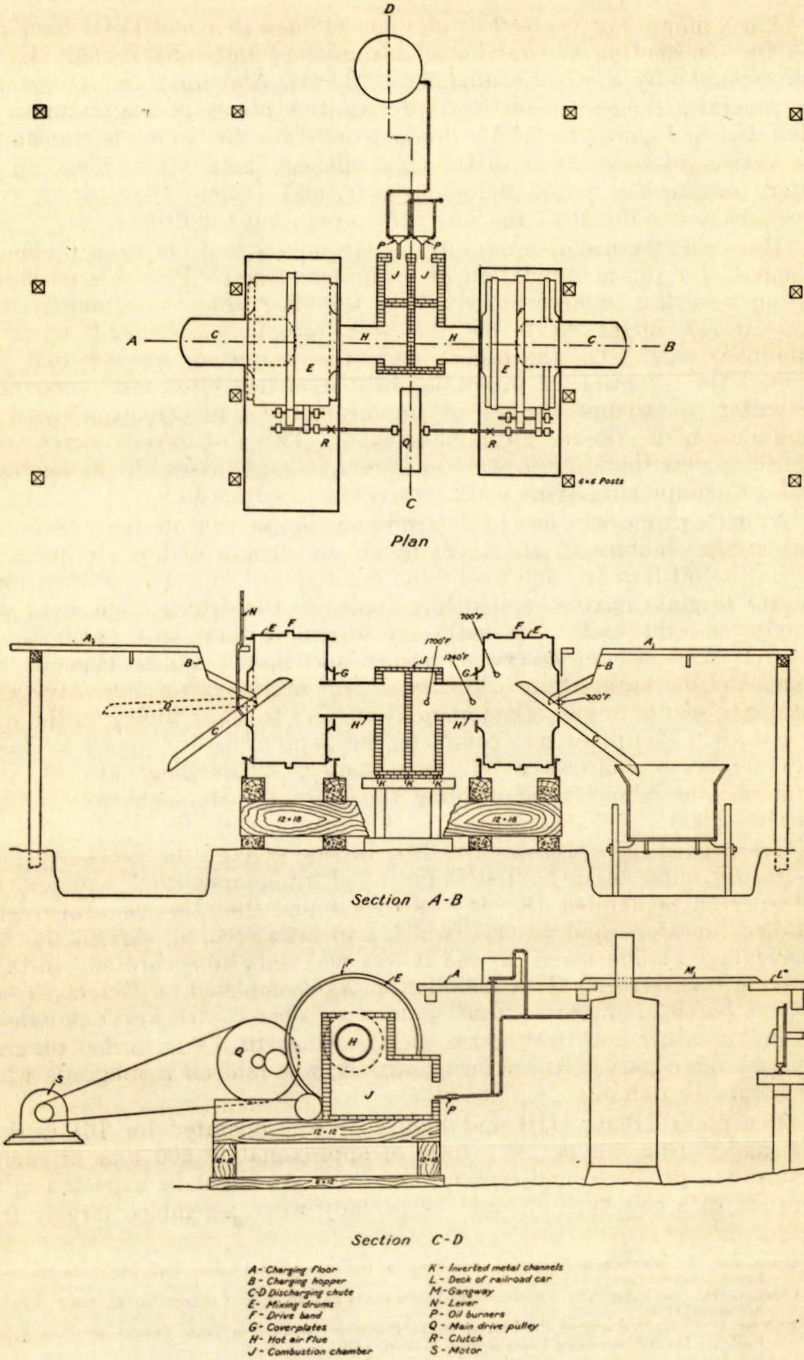


Figure 6. Semi-portable, internally heated mixing plant, Jasper, Alberta.

such second-hand materials as could be secured—certain minor defects developed, though none were sufficiently serious to interfere with continuous operation. It may be noted that the heavy transverse timber supports carrying the mixing-drum frames, also supported the combustion chamber. Consequently the vibration from the drums was transmitted to the combustion chamber and tended to loosen the fire-brick lining. Entirely separate supports for the drums and combustion chamber should be provided, unless the plant is equipped with roller bearings.

Possibly on account of the extended period of heating, smoke from the drums did not seriously inconvenience men working on the charging-platform. In Texas, however, rapid heating at higher temperatures and the addition of flux, at times, result in the production of large volumes of dense smoke. Under such conditions flues are sometimes installed immediately above the feed hopper, and the rock asphalt introduced through an opening at the base of the flue. At times steam is by-passed to a point near the base of the flue and hastens the removal of objectionable smoke. As an alternative to the installation of flues, gas masks are sometimes worn by operatives, apparently with satisfactory results.

The following brief comment is based on the operation of the plant at Jasper, and should prove of practical value to anyone who might wish to adopt the use of somewhat similar equipment.

Capacity of Plant

In considering dimensions indicated in the following notes, it should be remembered that current practice in the United States is based entirely on the practical experience of many operators. The writer considers, however, that the evolution of the drum type of mixing plant is still incomplete, and that certain modifications might be introduced with beneficial results. Indeed, at present, there are few plants in Texas where changes are not being introduced from time to time. Efficiency, and possible financial profit on operations, will depend on elimination of labour to the maximum extent, and on economy of fractions of minutes in weighing, crushing, and heating, and in loading, and discharging of drums.

Capacity of plant will depend chiefly on: (1) rate of heating, (2) rate of charging and discharging, and (3) size and relative dimensions of mixing-drums.

Rate of Heating

At Jasper, owing to limited capacity of drums and in order to prevent spilling of materials from drum openings, the bituminous sand was fed somewhat slowly and heated alone for a short period until it became plastic. Three to five minutes later, the clean aggregate was introduced. Consequently it is difficult to state definitely the actual period of heating which may be necessary with better designed drums. Moreover, certain obvious minor changes in design of drum openings and in diameter of flues will materially increase heating efficiency. Assuming, however, a throughput of 15 batches per $8\frac{1}{2}$ hours—as on October 12—the average time required for loading, heating, and discharging a 2-drum batch of 5,800 pounds was

34 minutes. The most rapid heating was effected when a batch of rather fine-grained mixture—85 per cent of bituminous sand and 15 per cent fine gravel—was heated to 325° F. in 17 minutes.

It is difficult to definitely indicate the capacity per 9 hours of 2-drum mixing plants in Texas, when crushing, heating, and fluxing rock asphalt (bituminous limestone). Each individual plant has distinctive features of its own which affect throughput capacity. A well-designed unit (two drums, each 8 feet in diameter and 6 feet long) with which the writer is familiar in San Antonio, has a capacity of approximately 240 tons of surface mixture per 9 hours; while a 2-drum plant (drums 6 feet in diameter and 6 feet long) has a capacity of approximately 100 tons. The average production of two 8-foot drums may be placed at from 2,000 to 2,400 square yards of 2-inch compacted surface per 9 hours. The writer is aware that a materially greater throughput is sometimes attained, but considers that this is nearly always at the expense of quality of product.

The rate of heating will depend on:

(*a*) Design, cubic capacity, and internal dimensions of combustion chamber; (*b*) type of burners, and permissible temperatures; (*c*) diameter and length of flues; (*d*) speed of drums; (*e*) condition of materials when fed into drums; (*f*) percentage of added clean aggregate.

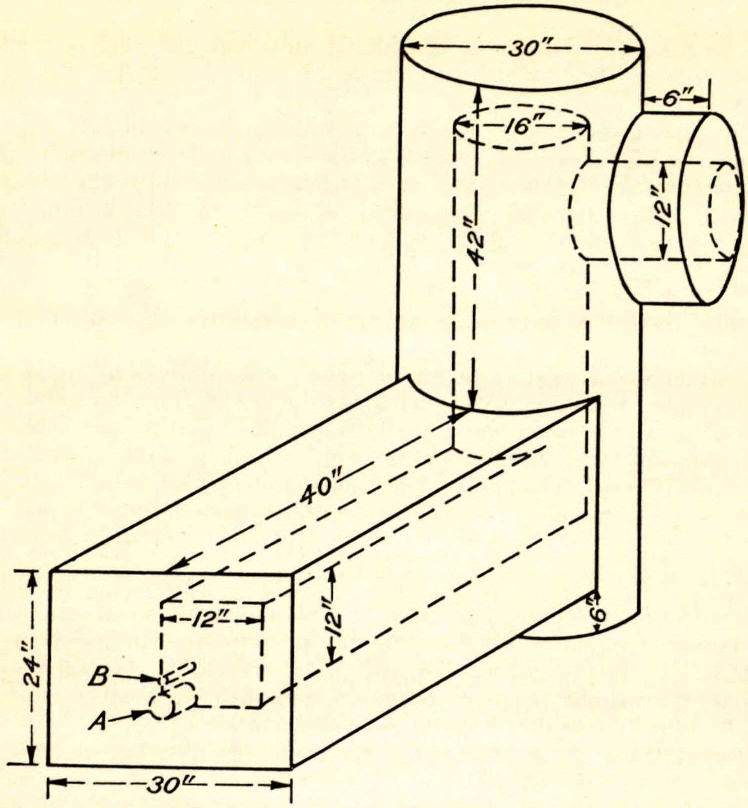
Design of Combustion Chamber. The three essential considerations in designing the combustion chamber are that it shall have sufficient cubic capacity to ensure complete and efficient combustion; that its length, or design, shall be such that the flame will not enter the mixing-drum, and that the installation be compact. Design will be affected by diameter, length, and capacity of mixing-drums. General types which have proved satisfactory—and of which there are a number of sub-varieties—are illustrated in Figures 7 and 8. Figure 7 illustrates dimensions and arrangement of combustion chamber used by the writer at Jasper. The fire-brick in this chamber was enclosed in a shell of $\frac{3}{32}$-inch sheet iron. At the end of two weeks the steel had become badly warped, accompanied by dislodgment of the fire-brick, and required reinforcing by means of angles. Apart from the question of weight, light cast-iron sheets would probably be more satisfactory.

It may be noted that the use of plastic fireclay appears to have distinct advantages over the use of fire-bricks. Thickness of the side walls and roof need not exceed 5 inches, but the back of chamber should be not less than 10 inches thick. Flat tiles, when used for the roof, have a tendency to crack, owing to expansion and contraction due to sudden changes of temperature.

So far as possible combustion chambers should be insulated—especially if adjacent to timber supports.

Type of Burners. The writer has successfully used both inside mixing-burners of the centrifugal type, and outside mixing-burners of the "drooling" type.[1]

[1] Both Gem and Coen burners have been found satisfactory. A third type of burner which has given satisfact at certain plants in Texas, is manufactured by The Fort Worth Machine Co., of Fort Worth, Texas.



A—opening for 6" air pipe.
B—opening for oil burner.

Figure 7. General type of single combustion chamber.

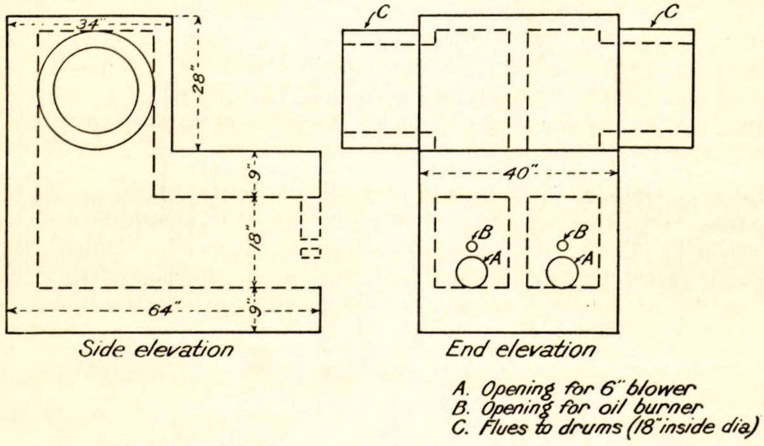


Figure 8 General type of double combustion chamber.

As a rule, one burner is considered sufficient for each combustion chamber, though at one plant with which the writer is familiar two burners are used.[1] At Jasper, as indicated in Figure 6, fuel-oil storage was provided for on the charging-platform, 6 feet above the oil burners. On cold mornings the oil tended to thicken, and a steam coil was installed in the bottom of the fuel-oil tank. This coil terminated in a half-inch pipe which was carried down through the centre of the fuel-oil line leading to the burners. As a result the fuel oil was entirely liquid at all times. The oil was atomized by steam under a pressure of 40 pounds from a 10-h.p. boiler, bleeders being provided where necessary to remove condensed steam. Apparently the use of compressed air for atomizing the oil would be preferable to steam.

It appears that the value of blowers with combustion chambers is debatable. In Texas, however, with notable exceptions, blowers are in general use. The blowers usually consist of small 6-inch fans (1200-1500 r.p.m.), delivering air through a 6-inch pipe. The writer's observation is that, unless combustion chambers are particularly well designed, the use of blowers is desirable. A satisfactory type of 6-inch steam blower used in Texas, is that manufactured by the Coppus Engineering Corporation, Worcester, Mass.

Diameter and Length of Flues. In plants operated by the Uvalde Rock Asphalt Company, hot-air flues project into the mixing-drums not more than two inches, whereas in the plant erected at Jasper, the flues projected approximately four inches. Consequently, charged materials tended to lodge on the upper surface of the flue and in the flue itself, where high temperatures frequently caused ignition. Shortening of the flues would remedy this defect.

Diameter and length of flue are not greatly affected by drum dimensions. In Texas, flues having an inside diameter of 12 to 18 inches and a length of 6 to 16 inches are used with both 6- and 8-foot drums. As originally installed at Jasper, dampers were provided in each flue. Later these were removed, and their practical value appears to be doubtful. Unless flues are insulated or constructed of fire-brick or its equivalent, heat losses by radiation will be serious.

Flues are usually constructed of specially shaped fire-brick, or of fireclay compounds, enclosed by sheet metal. Usually the metal housing terminates one or two inches from the drum, the flue being continued into the drum by the use of solid tile, or tile formed by two semi-circular sections.

Speed of Drums. This should be such that materials in the drum will fall almost vertically across the hot blast from the combustion chamber. The writer has found that with 6-foot drums, a speed of from 12 to 13 r.p.m. is satisfactory. Obviously, rate of heating will depend to a considerable extent on the frequency with which materials are cascaded downward through the hot blast.

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[1] Houston plant of the Uvalde Rock Asphalt Co.

Condition of Materials Fed into Drums. Bituminous sand as broken down at the quarry, may be in the form of small fragments or in masses several tons in weight depending on the manner in which shots are placed. Obviously the smaller the pieces fed into the drums, the more rapidly they will be disintegrated by the heat. Some form of preliminary disintegration, either by a mechanical device, such as heated toothed rolls, or by the use of a preheating chamber, will, if practicable, be a distinct advantage. It may be noted that during moderately cold weather—25 to 35 degrees above zero—bituminous sand fractures readily, and lumps may be easily reduced in size by sledging. During warm summer weather, however, the material can be sledged only with great difficulty. The amount of moisture in the bituminous sand used at Jasper varied from 0·2 to 2·7 per cent. Clean aggregate (crushed rock and gravel) also carried a high percentage of moisture, the total amount of water evaporated from each drum being probably 80 pounds per batch. As no drier was available, all evaporation was effected in the mixing-drums, and the rate at which this takes place will depend on relative dimensions of drums. It is clear that, with charges of equal volume, increase in length of drums will result in increased heating efficiency. It may be noted that a small percentage of moisture in the bituminous sand—or bituminous limestone—to some extent hastens disintegration during initial stages of heating. The advantage of drying the clean aggregate before charging requires no comment.

Percentage of Added Clean Aggregate. Particularly when clean aggregate carries a high percentage of moisture, it is clear that relative percentage of bituminous sand and of clean aggregate, and the density of the resultant mixture will be reflected in required periods of heating. With the equipment used at Jasper, the time required to heat a mixture of 65 to 70 per cent bituminous sand and 30 to 35 per cent of clean aggregate to 275 to 290° F, varied from 25 to 30 minutes. On the other hand, a mixture of 85 per cent bituminous sand and 15 per cent clean aggregate, was heated to 320 to 325° F. in approximately 17 minutes. Modified design of drums and hot-air flues should result in a materially increased rate of heating.

Rate of Charging and Discharging

Feed hoppers with inclined concave bottoms were found to be satisfactory, and are preferable to the screw conveyers used in connexion with "torpedo" type mixers. When shovelling with scoops over a plank charging-platform, 2,800 pounds of bituminous sand and clean aggregate were loaded by two men in from 2 to 2½ minutes, while 1½ to 2 minutes were required for discharging the batch into the street wagon. Time required for discharging varied, however, with temperature of batch, percentage of associated bitumen, and grading of aggregate. Thus a 2,800-pound batch—having an aggregate approximating that of a sheet asphalt mixture—carrying 11·5 per cent bitumen, and heated to 325° F., flowed rapidly and smoothly down the discharge chute and found its own level in the wagon, in from ½ to ¾ minute. On the other hand, the plasticity of a 9 per cent mixture, consisting of 70 per cent bituminous sand and 30 per cent crushed rock, was distinctly less at 300° F. A hoe, the edge of which was shaped to fit the concave bottom of the discharge chute, was used to expedite movement of the stiffer mixture, the time of discharge varying from $1\frac{1}{2}$ to $2\frac{1}{2}$ minutes.

Metal sheets on the charging-floor would be an advantage and, if used, should extend slightly over edge of feed hopper. This would prevent fine particles of clean aggregate falling through and adhering to the surface of the chute. Accumulation of such particles seriously affects smoothness of flow of the mixture while being discharged, and involves somewhat frequent and laborious scouring of chutes. At times smoke from the mixing-drums inconvenienced men on the charging-floor. This could be overcome by erecting flues over the feed hoppers. It is also desirable that the opening into the mixing-drum from the bottom of the feed hopper be closed during heating by means of a movable metal plate.

Sectional dimensions, length, and inclination of discharge chutes, materially affect rate of discharge, and consequently the capacity of the plant. With an inclination of 50 degrees, a mixture will be discharged at a sufficiently rapid rate, but the area of the transverse section of chute must be adequate to accommodate discharged material and prevent spilling on the roadway. With an inclination of 50 degrees, a depth of 8 inches and a width of not less than 20 inches is desirable. Chutes should be kept smooth and clean at all times, and the occasional application of heavy petroleum will facilitate movement of the heated material. Rapidity of discharge will thus be affected by the plasticity of the mixture, which in turn depends on temperature, density, and percentage of associated bitumen.

The distance to which the inner end of the discharge chute, when in the discharging position, extends into the drum, will depend on design and arrangement of the flights of mixing-blades. With drums 39 inches long it appears that a horizontal distance of 16 or 18 inches—rather less than one-half the length of the drum—is satisfactory.

With internally heated drums, temperatures and periods of heating are under complete control, and visual observation of the batch is possible at all times. Owing to the design and arrangement of the mixing-blades, a considerable proportion of the material is carried to the top of the drum, from which point it cascades downward in the form of a curtain. At Jasper a normal charge consisted of 1,800 to 1,900 pounds of bituminous sand and 800 to 900 pounds of added clean aggregate. Much of the bituminous sand, when charged, was in the form of lumps 6 to 10 inches across the face, and these were reduced, by heat and agitation, to fine particles in from 3 to 4 minutes. When first introduced into the mixing-drums, the lumps became rounded, and a minimum surface area, as compared with angular masses, was thus exposed to the action of heat. Preliminary crushing to small fragments would greatly increase surface area and consequently heating efficiency. Pieces of 2-inch compacted wearing surface, up to 12 inches square, returned from the road, were readily re-melted. Viewed through the drum opening, the charged materials were seen, after 3 to 4 minutes heating, as a dense, finely divided curtain falling across the disk of the white hot fire-brick background of the combustion chamber. As heating progressed, the individual particles tended to coalesce, forming irregular ropey masses, which finally took the form of large individual masses, or " blobs." (Figure 9). Observation of this transition of a constant mixture through the stages noted, will enable the operator to determine within a few degrees,[1] the temperature of a batch. Should the composition of the mixture be altered, with increase or decrease in the percent-

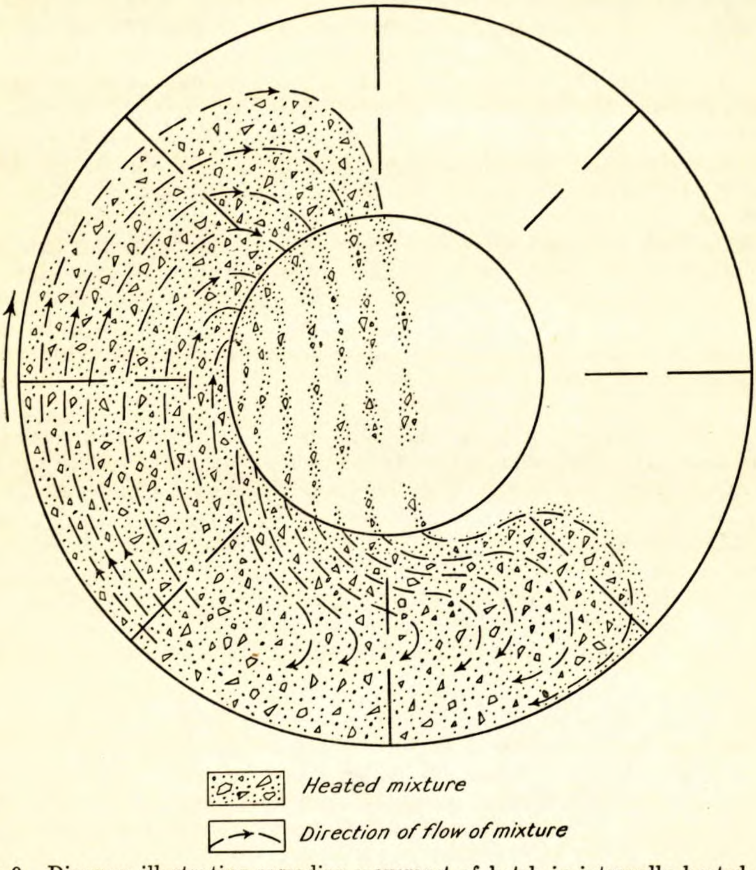


Figure 9. Diagram illustrating cascading movement of batch in internally heated mixer.

age of bitumen, or in modification in fineness of added clean aggregate, the change is at once seen, and carelessness in charging the drums may be detected. Thus, the consistency of a batch at 260° F., consisting of bituminous sand and of clean rock crushed to pass a one-inch ring, and containing 9·5 per cent bitumen, is such that it will flow down the discharge chute in an unbroken stream somewhat like porridge. If the proportion of

[1] At Jasper, the writer's estimate of temperatures, based on observation, was usually within 10 degrees of the actual temperature.

bitumen is increased to 10 per cent, the mixture flows like gruel. Increase or decrease in the size of the batch is at once reflected in the rapidity with which the material passes through the various stages noted.

In 1915, the writer installed at Edmonton, Alberta, the first heated mixer[1] designed for the manipulation of Alberta bituminous sand. This mixer was of the externally heated type, and the batches when discharged into the wagons, showed a temperature of 375 to 400° F. On the other hand batches when discharged into the wagons at Jasper, showed a much lower temperature—ranging from 265 to 290° F.—and it might be supposed that desired distillation of the lighter fractions associated with the bitumen would be incomplete. Owing, however, to the extremely efficient agitation in the internally heated drum, the finely divided particles of the mix, while falling through the blast of hot air, are exposed momentarily to temperatures ranging up to 700° F. On reaching the lower, and cooler, zone of the drum, a considerable part of this heat is imparted to the principal mass of the batch. When the charge is first introduced into the drums, volumes of white steam are given off. This changes to a light bluish colour as the temperature rises, but no brown fumes are discernible. As the individual particles coalesce more and more, the smoke diminishes in volume. When, however, a batch is discharged at 265 to 290° F., wisps of brownish yellow smoke are given off, indicating the high temperatures to which the bitumen is subjected when passing through the hot-air blast. Drum and combustion chamber temperatures as determined by means of a Hoskins thermo-electric pyrometer, are indicated in Figure 6.

It may be added that, since drums are partly open at the discharge ends, wind may materially affect heating efficiency. Consequently it is desirable to provide some form of protection, either wood or canvas. Atmospheric temperatures are also reflected in length of periods of heating. On cold mornings the time required to raise the temperature of the first batch, was appreciably longer than on warm mornings. Subsequently, when drums and combustion chamber had become thoroughly heated, atmospheric temperature appeared to have but little effect.

Size and Design of Mixing-Drums

Standard mixing-drums used by the Uvalde Rock Asphalt Co., are of two sizes, viz., 8 feet in diameter and 6 feet long, and 6 feet in diameter and 5 feet long. Charged capacity of an 8-foot drum varies from 3 to 4 tons of mixture. As previously noted drums used by the writer were approximately 6 feet in diameter and 3 feet 3 inches long. This somewhat restricted length caused undue crowding of the batch, and it is obvious that greater length would give better results.

Operation of drums from 6 to 8 feet in diameter presents no mechanical difficulties, but the relation between length and diameter is still a controversial matter. Increased length implies a longer period for discharging, but also provides greater capacity and permits of more efficient distribution and heating. In Texas, where batches are loaded and discharged at relatively frequent intervals of from 4 to 9 minutes, undue length would imply

[1] For description see Mines Branch Report No. 632.

serious loss of time in discharging. On the other hand, Alberta, and certain other types of bituminous sand, must be heated for much longer periods, and a somewhat slower rate of discharge at interals of from 20 to 30 minutes would not represent so great an aggregate loss of time.

From data available at present, it is not possible to definitely indicate relative drum dimensions that will give best results in the manipulation of Alberta bituminous sand, although for drums 6 feet in diameter the length should apparently be between 5 and 7 feet. At Big Springs, Texas, drums 6 feet in diameter and 6 feet in length, are being successfully operated by the General Construction Company, of Fort Worth, Texas. In Texas the charging and discharging opening in an 8-foot drum, is usually 24 inches in diameter. The flue opening is usually approximately the same, but in some plants the diameter is 4 inches less; corresponding openings in 6-foot drums are approximately 20 inches. In the drums used by the writer both openings were 30 inches in diameter. As the inside diameter of the drums was but 70 inches, charged materials tended to spill out. This defect was partly overcome by allowing the bituminous sand to become somewhat soft before introducing the clean rock aggregate and by charging the batch somewhat slowly. The addition of a narrow inclined lip or flange concentric with drum openings would deflect the charge slightly toward the middle of the drum and overcome this defect. Cover plates G, (Figure 6), at flue openings were not secured to the drum; consequently those openings were not properly closed, and charged materials spilled out here also. Securing the cover plates to the drums would overcome this defect.

Movement of mixture during progress of heating is illustrated diagrammatically in Figure 9, and will be relatively the same irrespective of drum dimensions. At Jasper, using a 30-inch discharge opening and a 70-inch (inside diameter) drum, and with a charge of 2,800 pounds, the depth of material in the lower part of the drum was approximately 18 inches. Consequently the mixture almost reached the lower edge of the discharge opening and, when heated above 325° F., tended to splash out. Increasing the length of the drums will remedy this defect.

Each drum was equipped with 24 mixer-blades, arranged in 3 flights, secured to the inner face of the drum and to each other by iron brackets. As previously noted, a normal batch for a 6-foot drum consisted, in addition to clean aggregate, of 1,800 to 1,900 pounds of lumps of bituminous sand, ranging in weight up to 20 or 30 pounds. During earlier stages of heating, the constant impact of these falling lumps threw a severe strain on the blades. Subsequently, as heating progressed, an even greater strain was that due to the thrust or impact of some hundreds of pounds of the heavy inert mass of the heated mixture against successive blades. Weight, material, and fastenings of mixing- and lifting-blades should, therefore, be such as to meet the above conditions. Design and arrangement of flights of mixing-blades will be governed by relative drum dimensions, and will, in turn, determine rate of discharging as well as mixing efficiency. While detail of design varies at different plants, a satisfactory arrangement is illustrated in Figure 10.

In Texas, the loading and discharging of drums is usually through the same opening, a pivoted, concave, metal chute, very similar to that used

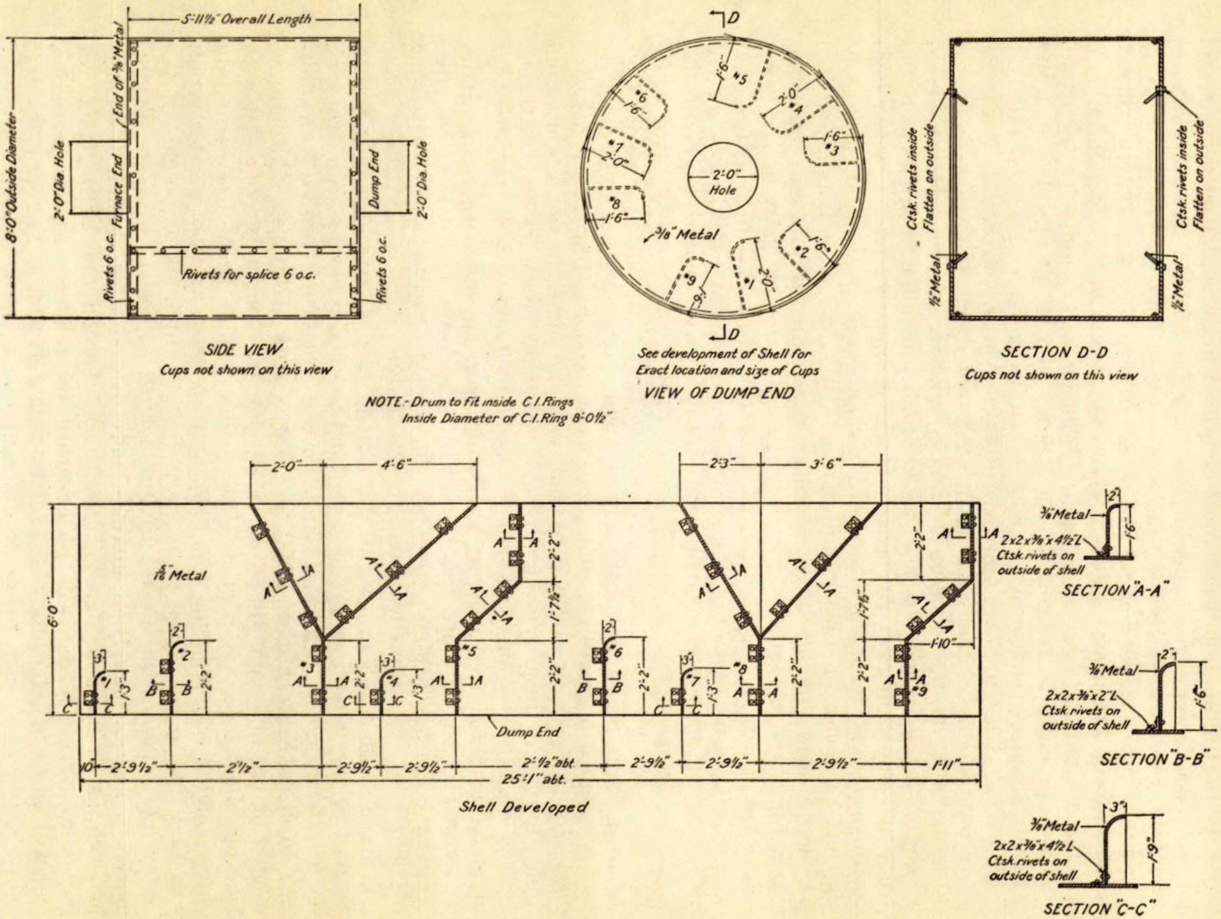


Figure 10. Typical arrangement of mixing- and lifting-blades in internally heated mixer.

on a concrete mixer, serving both purposes. Consequently after charging, the chute remains projecting into the drum where it tends to deflect the mix towards the centre. Such an arrangement did not appear to be suitable when heating Alberta bituminous sand. In Texas the rock asphalt is usually crushed to pass a $\frac{3}{8}$-inch ring and consequently the small particles of the batch, in cascading from the top to the bottom of the drum, do not injure the chute. On the other hand, Alberta bituminous sand was fed into the drums at Jasper in masses up to 30 pounds in weight, and the constant impact of these upon the chute would have been unduly severe. A special chute (Figure 6) was therefore designed and installed. During charging and mixing, the chute, which was operated by an overhead lever, was swung completely clear of the drum opening, and was lowered into the discharging position when mixing and heating was complete. The mechanical operation of the chute as installed was satisfactory. When withdrawn from the drum opening, however, the metal of the chute cooled to atmospheric temperature, and this tended to retard the flow of the heated mixture. It is clearly an advantage to keep the chute hot, and if the masses of bituminous sand are reduced in size by the use of rolls or otherwise, the chute should be so designed as to project into the drum at all times.

It is desirable to equip the drive shaft with clutches so that if necessary for any reason, one drum may be stopped independently of the other. Unless excess power is available, it is difficult to set both drums in motion once the heavy batches have settled to the bottom. By starting one drum at a time the batches may, however, be discharged. Clutches should be secured by means of set-screws designed to shear under unduly heavy strain.

To some extent scale forms on the interior surface of the drums. This may be removed while still warm or burned off when cold since the interior of drums is readily accessible. The introduction of small quantities of petroleum distillate, such as kerosene, when drums are running light, will also facilitate the removal of scale. The extent to which this accumulation retards rate of heating was not determined, but during $16\frac{1}{2}$ days' operation at Jasper, the scale was removed but once. Apparently scale has an adverse effect when heating up the drums in the morning, since the clean metal of the drums would absorb heat much more rapidly than the scale itself. Once the scale has acquired drum temperature, however, its effect is probably slight.

Power for operating the two drums at Jasper was supplied by a 15-h.p. 550-volt, 60-cycle, 3-phase A.C. motor having a speed of 850 r.p.m. The 8 by 8 pulley on the motor was connected by an 8-inch belt to a 44- by 11-inch split pulley secured to the main drive shaft. The shaft speed was reduced by means of gears to give the drums a speed of approximately 12·5 r.p.m.

In Texas approximately 150 h.p. is required to operate a unit of two 8-foot drums. This power also operates certain auxiliary equipment including crusher, elevator, pumps, etc.

CHARACTER OF WEARING SURFACE

The mixture laid at Jasper (Plate VB) may probably be best described as a stone-filled sheet asphalt. Width of wearing surface is 15 feet increased to approximately 20 feet at curves. The writer considers that, under local conditions, this width is insufficient and that subsequent widening to 18 or 20 feet will not give satisfactory results. For the most part, compacted thickness is approximately 2 inches. When laid on a base other than Portland cement concrete, a somewhat thicker wearing surface appears desirable. A binder course, having a maximum thickness of 1½ inches, carrying possibly 5 per cent asphalt cement, and a 2-inch wearing surface, has been suggested by R. C. Marshall of the Crown Paving and Construction Company. The question of thickness and character of wearing surface which will give best results—and the correlated problem of laying and rolling—presents an important field for further practical investigation.

Each car of bituminous sand on arrival at Jasper (Plate VA) was core sampled (Table II) and percentage of bitumen, percentage of moisture, and grading of sand aggregate determined. During summer weather it should be possible to complete sampling and laboratory determinations in three hours. During cooler weather, when the bituminous sand is frozen to some extent, sampling will require more time and care.

TABLE II

Abridged Analyses[1] of Representative Samples of Bituminous Sand as Sampled on Cars at Jasper

Sample No.	Moisture	Passing mesh							Retained on 10	Per cent associated bitumen.
		200	100	80	40	30	20	10		
1	0·3	1·2	8·6	5·7	69·5	9·4	2·3	3·3	0·02	13·5
2	1·2	1·4	13·7	7·3	60·4	7·5	7·4	2·4	....	12·5
3	0·8	1·7	18·4	4·8	60·0	8·8	5·1	1·6	....	12·3
4	0·8	1·4	18·6	5·8	57·7	7·3	7·4	1·9	....	12·2
5	0·2	1·3	13·1	3·6	67·2	6·5	5·9	1·5	0·6	14·2
6	0·6	2·5	17·7	4·0	63·0	6·5	5·0	1·2	....	12·7
7	0·6	1·7	15·5	3·9	64·3	6·2	6·2	2·2	....	14·5
8	2·7	1·2	14·5	2·7	69·3	6·1	4·7	1·2	....	12·1
9	1·2	0·8	11·2	2·5	69·0	7·8	6·1	2·5	....	14·6
10	1·0	1·6	15·4	4·1	64·3	6·1	6·0	2·2	0·3	13·5

[1] The bed of bituminous sand from which shipments were made had been subjected to severe shearing (owing to weight of overburden) with subsequent infiltration (along slip planes) of variable amounts of water. This will probably account for variation in indicated percentage of associated bitumen. For detailed analyses of McMurray bituminous sand and results of physical determination, see Mines Branch Report No. 632.

Clean aggregate incorporated with the bituminous sand, consisted of crushed limestone and somewhat fine pit gravel (Table III). The limestone was crusher run rock, broken to pass a one-inch ring, and was supplied by the Marlboro Cement Company. Gravel and crushed rock were both passed through a rock screen and a part of the material passing a ¼-inch mesh, as well as material having a diameter greater than one inch, removed. The crushed limestone and pit gravel were not dried prior to screening, and carried varying percentages of moisture according to weather conditions. Consequently grading of screened aggregate was not uniform, a condition which is reflected in analyses shown in Table IV. It is clear that drying of the clean aggregate before screening would not only have decreased the period of heating, but would also have resulted in a more uniform product.

TABLE III

Grading of Screened Aggregate Used at Jasper

—	Passing mesh										Retained on 1"
	200	100	80	40	30	20	10	¼"	½"	1"	
Crushed limestone..	0·4	1·8	0·7	3·5	2·1	3·2	9·2	33·9	21·2	21·8	2·1
Pit gravel..........	0·5	1·7	0·1	4·2	4·1	8·3	18·9	37·1	7·5	13·3	4·1

Using results of analyses as a guide, the necessary number of barrows of bituminous sand and of crushed rock were then wheeled onto the charging-platform A, (Figure 6), discharge chute C, was swung by means of lever, N, into position, D, and the charge of bituminous sand and clean aggregate fed into the revolving drums, E. When heating and mixing were complete, chute C was lowered and the mixture discharged into wagons or trucks.

TABLE IV

Typical Analyses of Paving Mixtures used at Jasper, Alberta

No.	Passing mesh										Ret. on 1"	Per cent A.C.
	200	100	80	40	30	20	10	¼"	½"	1"		
1........	0·9	8·8	3·0	52·1	5·2	3·8	1·6	11·6	6·8	6·1	0	9·3
2........	0·9	12·1	2·5	49·1	5·6	3·7	1·2	9·9	5·4	9·6	0	9·2
3........	0·8	5·4	13·1	39·7	......	10·9	1·8	5·4	21·2	1·7	0	9·3
4........	1·3	9·8	2·8	44·7	4·3	4·8	7·2	18·0	4·5	2·5	0	9·7
5........	0·9	5·3	1·3	48·9	4·4	5·0	6·6	21·0	2·5	4·2	0	9·5
6........	0·7	6·3	3·1	50·0	4·8	4·6	4·5	21·4	2·0	2·6	0	9·2
7........	0·8	5·5	0·9	50·3	5·1	5·3	5·2	19·0	3·7	4·1	0	9·2
8........	0·8	4·3	0·6	53·5	5·6	6·0	7·3	18·0	1·9	1·9	0	9·3
9........	1·2	12·2	6·3	42·0	4·6	4·5	5·2	17·3	3·9	2·7	0	9·7
10........	1·3	10·2	3·9	43·6	4·7	4·9	6·5	16·0	3·5	5·3	0	8·7
11........	0·9	10·9	3·7	43·7	5·1	5·6	7·1	15·7	2·5	4·9	0	9·7

In order to obtain a paving mixture carrying from 9 to 10 per cent asphalt cement, relative proportions of bituminous sand and clean aggregate were varied from time to time according to analyses of core samples of the bituminous sand. As no facilities were available for weighing the ingredients of each batch, the weight of a wheelbarrow of clean aggregate and of bituminous sand was determined and used as a basis of measurement. Since the personnel employed was changed frequently, the above method was not conducive to securing uniformity in the batches as will be seen by results indicated in Table V. Obviously an increase in the 200-mesh material by the introduction of some satisfactory filler is desirable.[1]

As previously noted, batch temperatures were materially lower than those adopted in connexion with demonstration paving in Edmonton in 1915. Average periods of heating were also somewhat less. This is reflected in the following determinations of bitumen separated from average batches.

TABLE V

Physical Characteristics of Bitumen used at Jasper

—	Batch 1. Heated for 25 min. Max. temp. 260°F.	Batch 2. Heated for 30 min. Max. temp. 260°F.	Batch 3. Heated for 27 min. Max. temp. 325°F.	Batch 4. Heated for 30 min. Max. temp. 325°F.
Penetration of A.C., at 77°F., 100 grms., 5 sec..	too soft	too soft	206	112
" " 77°F., 100 grms., 1 sec..	237	155	115	60
" " 32°F., 100 grms., 5 sec..	90	65	44	31
Ductility at 77°F..............................	100 c.m. +	100 c.m. +	100 c.m. +	100 c.m.+
" 115°F..............................	"	"	"	"

From the above table it will be seen that the penetration of the asphalt cement is high and in the case of batches 1, 2, and 3, should be materially reduced. Within reasonable limits and with a properly balanced aggregate the high penetration does not necessarily indicate a source of weakness for, as a rule, it is usually some months before bituminous sand pavements acquire their permanent set. During this interval the surface is frequently marked by traffic to a considerable extent, and may be adversely criticized.

Immediately after spreading and raking, the bituminous sand mixture was compacted by means of a hand roller weighing approximately 300 pounds. After the wearing surface had cooled somewhat, final compression was effected by the use of a standard 7-ton tandem roller. The writer has found that, with a mixture equivalent to sheet asphalt, heated to a temperature of 350° to 400° F., a period of 2½ to 3 hours should elapse before the heavy roller is used. This period will, however, depend chiefly on type of mixture, atmospheric temperature, and wind. No arbitrary rules can be given with regard to final rolling, and this should be left to the discretion of the roller man.

ESTIMATED COSTS

It is somewhat difficult to deduce accurate cost data from the paving work undertaken at Jasper during October, 1926. Conditions were not such as would prevail under established commercial practice, and neither plant nor road personnel operated at capacity.

Cost of unloading cars possibly constitutes the most important single factor in any cost estimate on the commercial use of bituminous sand. Cost and speed of unloading will depend largely on weather conditions and on

[1] MacNaughton, Moray F.: New Theory of Asphalt Mixtures (1925).
Publications of the Asphalt Association, New York City.
The Value of Hydrated Lime as a Filler in Asphalt Paving Mixtures, Bull. 318, National Lime Assn., Washington, D.C. (1926).

character of material. During cool weather—as for example under 40° F.—the lumps do not compact to any serious extent, while during warm summer weather the whole mass on the car tends to consolidate. Low-grade material can also be unloaded more readily than the richer grades. In California unloading costs were greatly reduced by the City Street Improvement Company by the use of two large wooden trays on each flat car. The corners of these trays were fitted with heavy lugs and, on reaching the paving plant, the trays were lifted from the cars by means of a derrick and the contents expeditiously dumped. Cost of loading and unloading will also depend on the type of cars used. It is hoped that an opportunity will be given shortly to secure data on this important matter. During 1926, the writer used standard flat cars equipped with board sides secured to temporary stakes. This involved the loss of valuable material, constituting a serious charge per ton, and would not be practicable for large and continuous operations.

The internally heated mixing-drums referred to above were operated for 16½ days. The first batch was charged about 7.30 a.m., the plant closed down for one hour at noon, and on account of darkness the last batch was discharged at 5.15 p.m. The average period of operation per day was thus rather less than 9 hours. During the 16½ days, 210 batches were passed through each drum, equivalent to a total of approximately 500 tons of mixture.

The average period of heating was about 30 minutes per batch, and from 5 to 7 minutes were required for charging the drums and discharging the heated mixture. Approximate costs were as follows:

Wages, 8 men at 45 cents per hour..	$36 00
Wages, 1 man (steam engineer) at 60 cents per hour (11 hours)	6 60
Fuel oil at 10 cents per gallon..	8 00
Gasoline for engine operating rock screen, and coal for boiler	5 00
Motor, 15 h.p., for operating drums..	3 00

Assuming an average of 14·2, 5,500-pound batches per day, this is equivalent to approximately $1.50 per ton of mixture, or 15 cents per square yard of 2-inch compacted surface.

At Jasper, the capacity of drums was small and labour-saving devices, such as crusher or elevators, were not introduced. On the other hand, cost of operating two drums, 7 feet in diameter and 6 feet long, would not be proportionately greater, while the combined capacity would be not less than 5 tons per batch. Throughput per 10-hour day should be approximately 125 tons of surface mixture. The use of some type of crusher, such as heated toothed rolls, a conveyer belt or elevator, and a light compressor in place of the steam boiler, would eliminate services of two men and increase power costs by $6 per day. On the above basis, estimated costs at or near Edmonton should be approximately as follows:—

Wages, 6 men at 45 cents per hour..	$27 00
Fuel oil at 10 cents per gallon..	10 00
Power..	9 00
Supervision..	5 00
Contingencies (10 per cent)..	4 50

With a capacity of 125 tons of mixture per day, plant costs would, therefore, be approximately $55.50, or 44 cents per ton.

Assuming large-scale operations and the use of labour-saving equipment, cost of placing bituminous sand on the cars at McMurray should not exceed 50 cents per ton. Assuming, also, a freight charge from Waterways to Edmonton of $3 per ton, clean aggregate at $2.20 per ton and a mixture equivalent to 70 per cent bituminous sand and 30 per cent clean aggregate, costs of materials at or near Edmonton would be approximately $3.11 per ton. With plant costs of 44 cents per ton, the total cost, apart from overhead, profit, etc., would be approximately $3.55 per ton of surface mixture. Assuming hauling costs from plant at $1.30 per ton, and street work at $4.50 per ton, total cost of material in place would apparently be approximately $9.35 per ton, or 93 cents per square yard 2-inch compacted surface. Corresponding costs of oil asphalt mixtures at Edmonton and at Winnipeg were (1926) approximately $1.25.

APPENDIX

The recognition of the merits of cracked gasoline, and the increasing tendency toward the complete conversion of crude petroleum—with coke and gas as by-products—appears to point toward decreasing supplies of residuum for paving purposes. Considering the wide distribution of rock asphalts in America, and the radius to which this class of material is now being successfully shipped, it appears that any deficiency in the supply of residuum need cause no apprehension.

In Mines Branch Report No. 632, brief reference was made to development of certain rock asphalt deposits in California, Texas, and Kentucky. Since the above report was written, development of rock asphalt deposits in Colbert county, Alabama, has attained important dimensions.[1] At present (March, 1927) active operations are being carried on near Cherokee and Margerum on the Southern railway.

ALABAMA ROCK ASPHALT, INC.

Near Margerum, Alabama, Alabama Rock Asphalt, Inc., is developing an important deposit of asphaltic limestone. The material quarried consists of a rather fine-grained, pisolitic limestone with which is associated from 5 to 8·5 per cent of bitumen, which has a penetration of approximately 14. Since the percentage of bitumen is insufficient for paving purposes, the deficiency is made up, by the introduction during heating and mixing, of the necessary percentage of asphaltic cement. The average thickness of the bed being developed is approximately 10 feet. Overburden is relatively light—varying from 1 to 12 feet in thickness—and can be readily removed without the use of explosives.

Prior to 1927, more than 30,000 tons were shipped from the Margerum quarry. At present (March, 1927) in order to increase production and facilitate movement of shipments, new equipment is being installed. A standard-guage railway, with 85-pound steel, is being built from the main line of the Southern railway to the quarry, a distance of approximately 2·25 miles.

Other new equipment includes: a large, Buchanan, steel jaw crusher having a capacity of 125 tons per hour, a No. 8 and No. 4 Williams pulverizers with a combined capacity of 125 tons per hour, twenty 6-cubic yard, standard-gauge, Koppel, steel-lined dump cars, a large, Sullivan, synchronous, electric-driven air compressor, a No. 600 P. & H. gas shovel, and a No. 600 P. & H. electric caterpillar crane. The normal capacity of the plant per 10 hours is 1,000 tons of pulverized asphaltic limestone.

Twenty-four well-built comfortable homes are being erected for housing employees of the company, in addition to a substantial office

[1] Clark, G. H.: Rock Asphalts of Alabama and their use in Paving, Geol. Surv. of Alabama, (1925).

building and company store. The total expenditure involved in the above construction will be in excess of $300,000. The capacity of the quarry will not be less than 1,000 tons of crushed rock asphalt per 10 hours. Already a large tonnage of rock asphalt from the above quarry has been contracted for which will involve a maximum rail haul of 1,000 miles.

ROCK ASPHALT CORPORATION

The property controlled by the Rock Asphalt Corporation is situated approximately 3 miles southeast of Cherokee station, Alabama, on the Southern railway. The quarries are reached by a standard-gauge track equipped with rolling stock owned and operated by the company.

The rock asphalt quarried is an asphaltic or bituminous sandstone which varies in thickness from 6 to 15 feet. The principal bed now being worked has an average thickness of 10 feet. The material consists chiefly of sandstone carrying 10 to 12 per cent of carbonate of lime and with which is associated varying amounts of bitumen up to 15 per cent. Analyses of rock shipped by the company, indicate an average bitumen content of 7 to 9 per cent. Overburden is from 5 to 12 feet thick, and consists chiefly of clay and earth. It is claimed that this occurrence represents the only known workable deposit where the above percentage of lime is found intimately associated with silica.

Equipment at the quarry includes: 13 side-dump, 20-ton cars, 3 steam shovels, 1 air compressor, 1 steam boiler, 7 drills, 2 core drills, 1 locomotive.

After the overburden has been removed, the rock asphalt is broken down by the use of 40 per cent gelatin powder. It is then hauled in side-dump, 20-ton cars to the crushing plant, where it is passed through an Allis-Chalmers Fairmount crusher having a capacity of 250 tons per hour, and reduced to a size which will pass a 4-inch ring. From the primary crusher, the material is carried by a 42-inch rubber belt conveyer to a 500-ton storage bin. By a platform conveyer it is carried (by a 30-inch belt conveyer), to an Anaconda 24-inch corrugated or rough roll, where it is further reduced to pass a 1½-inch ring.

The product is then conveyed by belt conveyer to a second Anaconda 24-inch smooth roll, and reduced to ¼ inch or less. It is then transferred by bucket elevator belt conveyer to a 48-inch Jeffrey hammer mill where it is pulverized. The finished product is conveyed by a 24-inch belt conveyer to the cars for shipment, or the stock pile as required.

The plant, which was designed and equipped by the Allis-Chalmers Company, is electrically operated throughout and has a capacity of 2,000 tons per day. It is stated that expenditure on plant and equipment to date is not less than $1,000,000. Shipments are being made to points which involve a maximum rail haul of 1,000 miles.

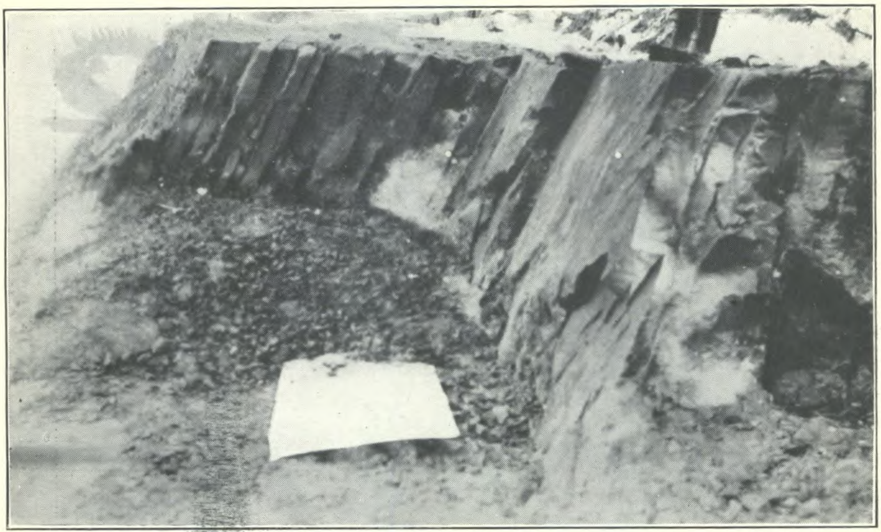
COLBERT LIMEROCK ASPHALT CO.

The rock asphalt quarry operated by the above company is located approximately 2 miles east of Cherokee station on the Southern railway. The material shipped is an asphaltic limestone carrying from 4 to 6 per cent bitumen. The thickness of the bed opened up varies from 4 to 16 feet, with an average of approximately 6 feet. Overburden, much of which is solid rock, varies in thickness from 1 to 50 feet.

Apart from administrative buildings and housing accommodation for company employees, equipment comprises: 2 steam shovels (Erie and Bucyrus), 4 Sullivan air drills, 1 Worthington air compressor, 8 dump wagons, 1 steam locomotive, 1 gas locomotive, 40 dump cars ($1\frac{1}{2}$ yards capacity), 2 Williams-Jumbo crushers (1 steam, 1 electric).

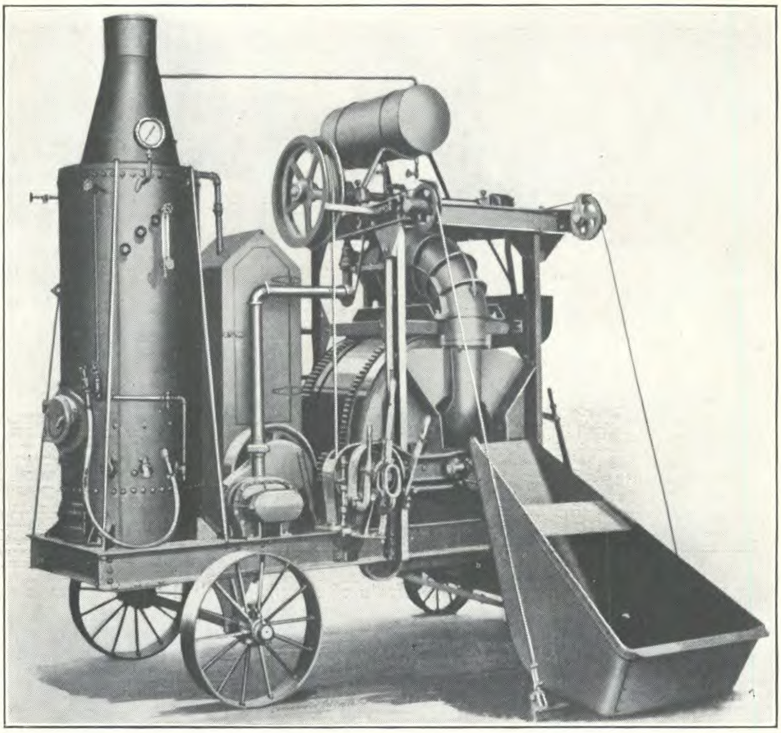
The rock asphalt is broken down by the use of 40 per cent gelatin powder and loaded by steam shovel into cars. These are hauled over a 24-inch gauge railway to the crushing plant, a distance of $\frac{3}{4}$ mile where two Williams-Jumbo crushers having a total capacity of 125 tons per hour, reduce the rock to pass a $\frac{9}{32}$-inch ring. The crushing plant is located on a spur line, $\frac{1}{2}$ mile long, connecting with the Southern railway, and the crushed product is loaded direct into standard 50-ton gondola cars. The above plant and equipment represents an expenditure of not less than $200,000. During 1926 shipments to points in Alabama, Tennessee, Missouri, and Louisiana involved a maximum rail haul of 375 miles.

PLATE I



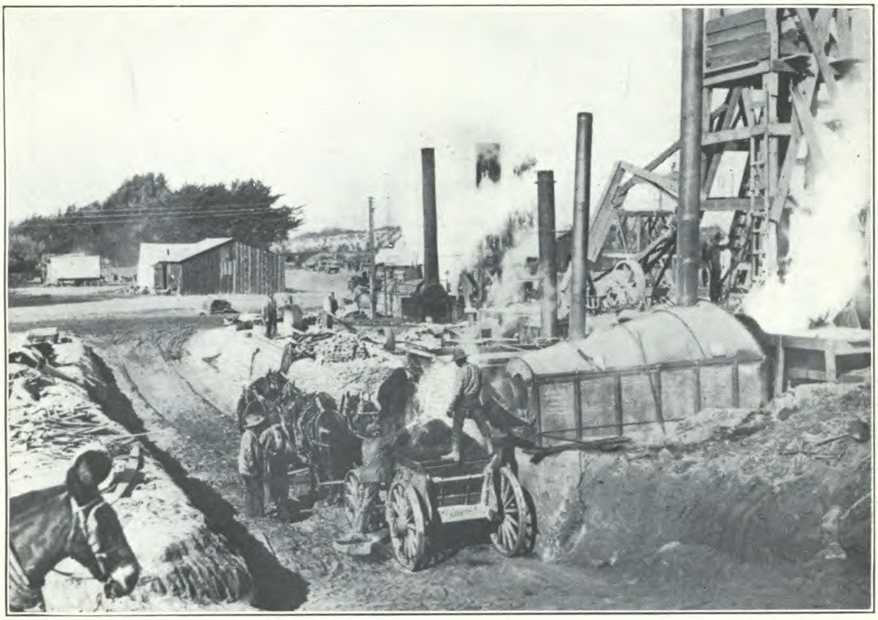
A. Quarry face at McMurray showing effects of slipping in bed of bituminous sand.

B. Opening up bituminous sand quarry at McMurray. The upper limit of bituminous sand is indicated by broken line.

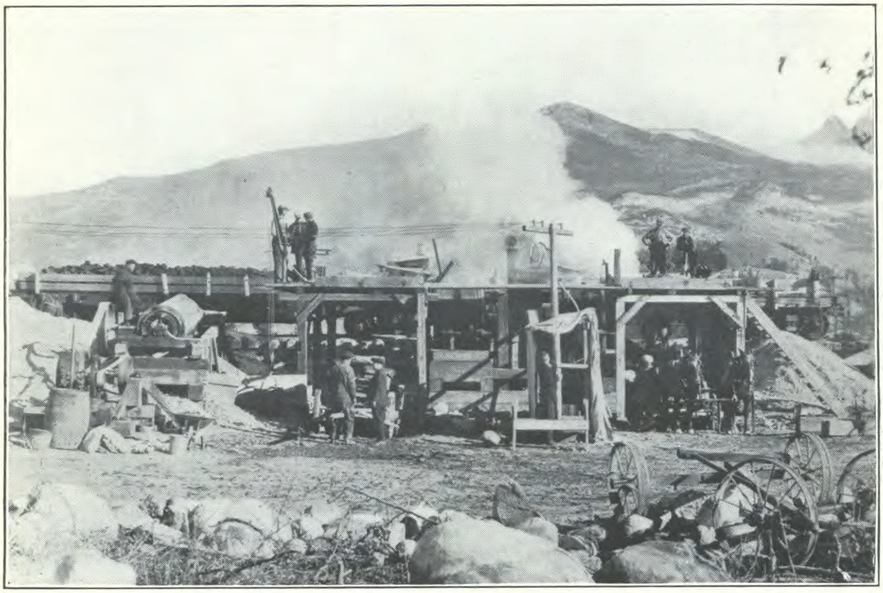


A. Portable, internally heated mixer.

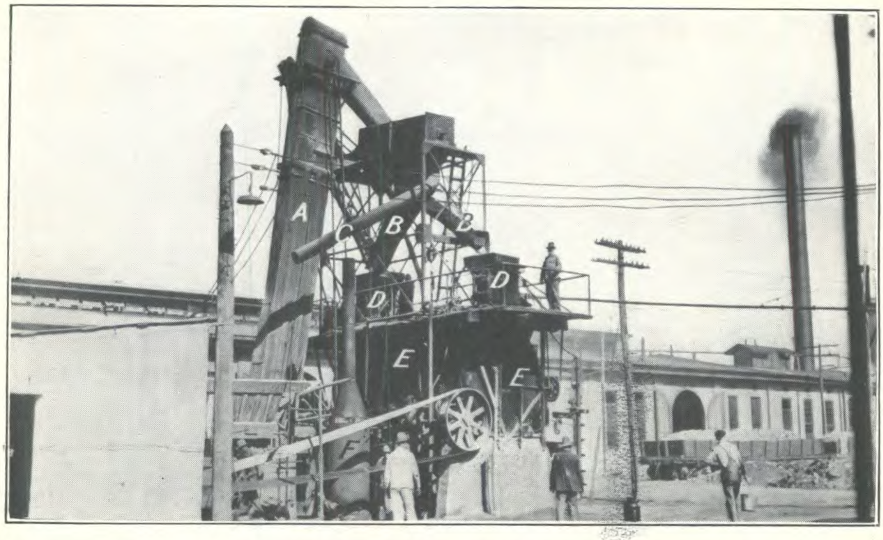
B. Portable, externally heated mixing plant (railroad type), California.



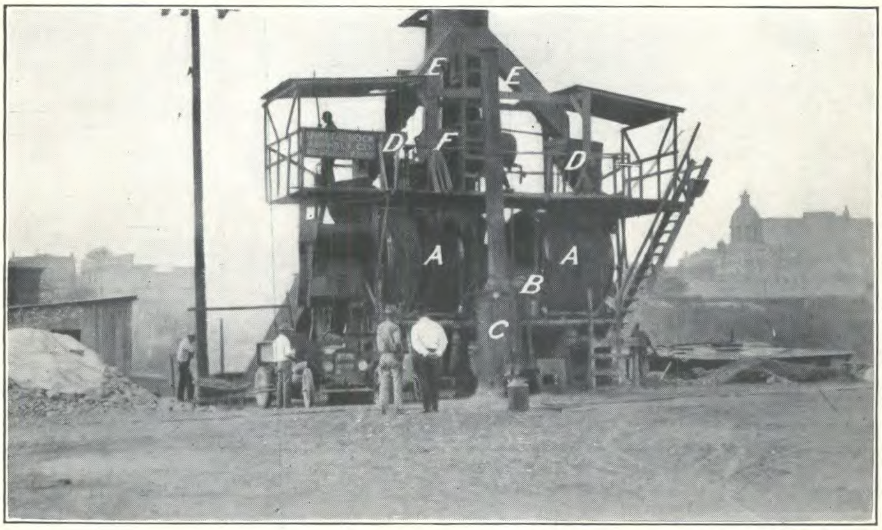
A. Semi-portable, externally heated mixing plant, California.



B. Semi-portable, internally heated mixing plant, Jasper, Alberta.

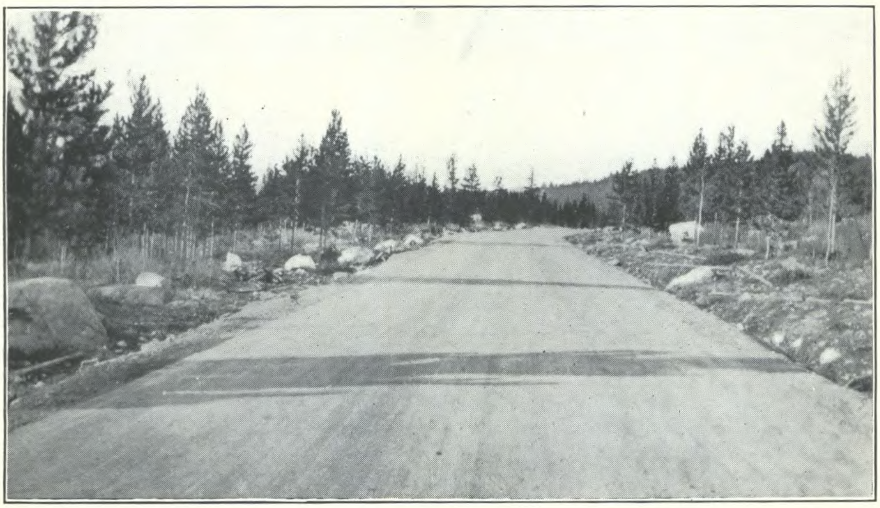


A. Two-drum, internally heated mixing plant; Uvalde Rock Aspahlt Company, San Antonio, Texas. A, elevator; B-B, discharge chutes from elevator; C, dust catcher; D-D, feed hoppers; E-E, mixing-drums (8 feet diameter and 6 feet long); F, steam boiler.



B. Two-drum, internally heated mixing plant; Uvalde Rock Asphalt Company, Houston, Texas. A-A, mixing-drums (8 feet diameter and 6 feet long); B, burner end of combustion chamber; C, steam boiler (for atomizing fuel oil); D-D, feed hoppers; E-E, discharge chutes leading from elevator to drum hoppers; F, flux storage.

A. First commercial shipment of Alberta bituminous sand for road-surfacing purposes arriving at Jasper.



B. First commercial use of Alberta bituminous sand for road surfacing.