5 Aggregate Production

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CHAPTER FIVE:
AGGREGATE PRODUCTION

This chapter discusses the total process of aggregate production from extraction through processing. Also discussed is the handling, stockpiling, and shipping of the product up to the point where the material leaves the Producer's control. Processing influences mineral quality and integrity, aggregate physical properties, and, in particular, gradation (size control). Establishing a stable production process may reduce variability of the product.

EXTRACTION

With the exception of slag and other manufactured aggregates most materials for aggregate production come from bedrock or unconsolidated deposits. The vast majority of materials used in the mineral aggregate industry are obtained from surface-mined stone quarries or from sand and gravel pits. How materials are extracted influences their quality.

Extraction Influences on Quality

STRIPPING

- **Not clean enough**
- **Spillage over mining face**

DRILLING AND BLASTING

- **Hole size, depth, and spacing (pattern)**
- **Blast delay sequence**
- **Blast intensity or charge**

SHOTROCK OR GRAVEL BANK

- **Non-uniform load-out**
- **Equipment changes**
- **Geologic variability**
- **Moisture variability in shotrock**
- **Above/below-water gravel deposits**

STRIPPING

As a first step, a Producer is required to designate a detailed stripping procedure (Figure 5-1) for each and every deposit that is mined. This phase often is overlooked, yet has a great influence on the quality and variability of the product. Inadequate removal of overburden from the mineral deposit often may be the source of excessive variation in minus No. 200 material and may even have a deleterious affect on nearby vegetation and other aspects of the mine.

For example, excessive knobs and depressions on the surface of a stone deposit may necessitate the use of smaller equipment or special techniques to clean the stone. Inexperienced equipment operators may easily corrupt good stripping practices (which are somewhat of an art and site specific). Spillage over the working face and other sloppy practices can also affect the cleaning process.

Figure 5-1. Stripping

Quarry operators commonly design fragmentation shots for safety, economy, ease of use at the primary crusher, and even public relations, but they often forget about quality.

The shot layout is required to be properly engineered, documented, and adhered to for maximum consistency. Varying the shot pattern may mean changes in product size throughout the operation. Smaller shot rock, resulting in less crushing in the secondary and tertiary stages, may mean less improvement through crushing. Therefore, the mineral quality and/or changes in physical properties of the product may be affected.

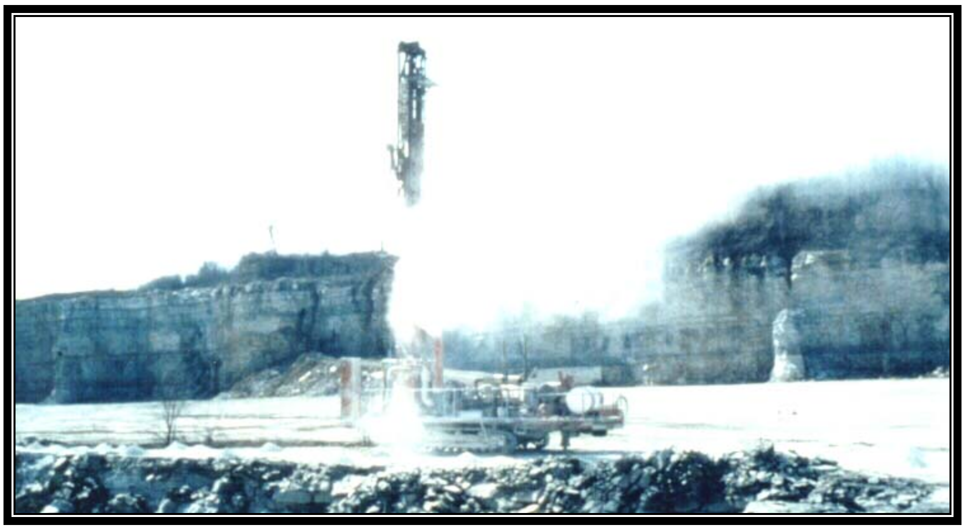


Figure 5-2. Drilling

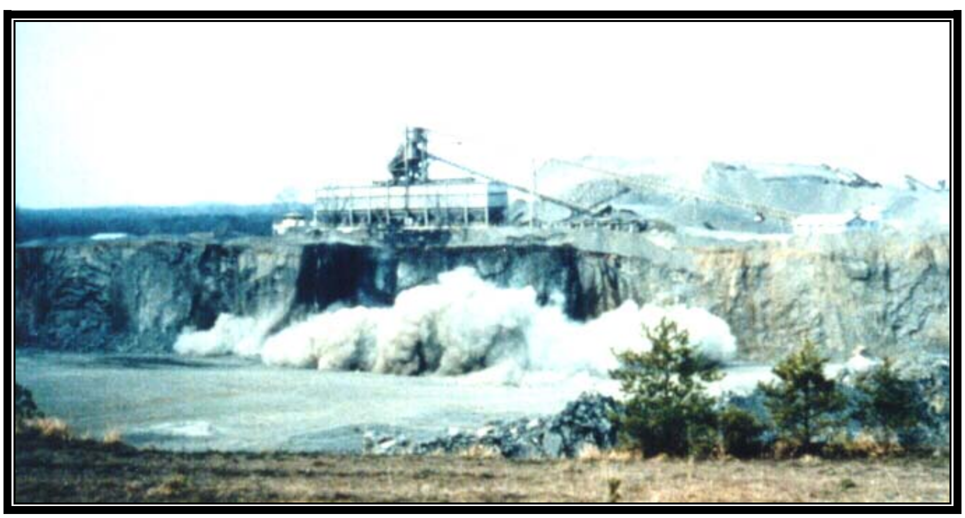


Figure 5-3. Blast or Shot

Hole detonation-sequencing and blast intensity also are required to be properly engineered. Size changes resulting from inattention to detail can have the same effects as mentioned above. Also, an erratic blast that throws the shot rock over a large area tends to cause variation in size gradation that is delivered to the primary crusher. Any deviation from previously established shot patterns, sequencing, and intensity should be carefully thought out as to the effect on product quality. Production changes are required to be documented in the Producer's Quality Control Plan and notification is required to be given to INDOT.

SHOT ROCK OR GRAVEL BANK

A constant problem of gravel pit and quarry operators is the difficulty in maintaining uniform load-out from either the shot rock pile or the gravel bank. Even the best shot has some variation from side to side and from front to back. Only experienced and well-trained equipment operators may accomplish the mixing from around the shot for the most uniform feed to the processing plant.

Subsurface sampling and testing are required to inform gravel-pit managers where the size of the material changes. In many cases, for example, material from both above and below ground water level is required to be blended in a prescribed manner to maintain uniform feed to the plant.

Changes in equipment, if done without thought as to how to maintain uniform sizing, also may have the same effect. Any change in equipment is required to be evaluated for effect. These changes are incorporated into an adenda to the Producer's Quality Control Plan.

Figure 5-4. Loading Quarry Truck

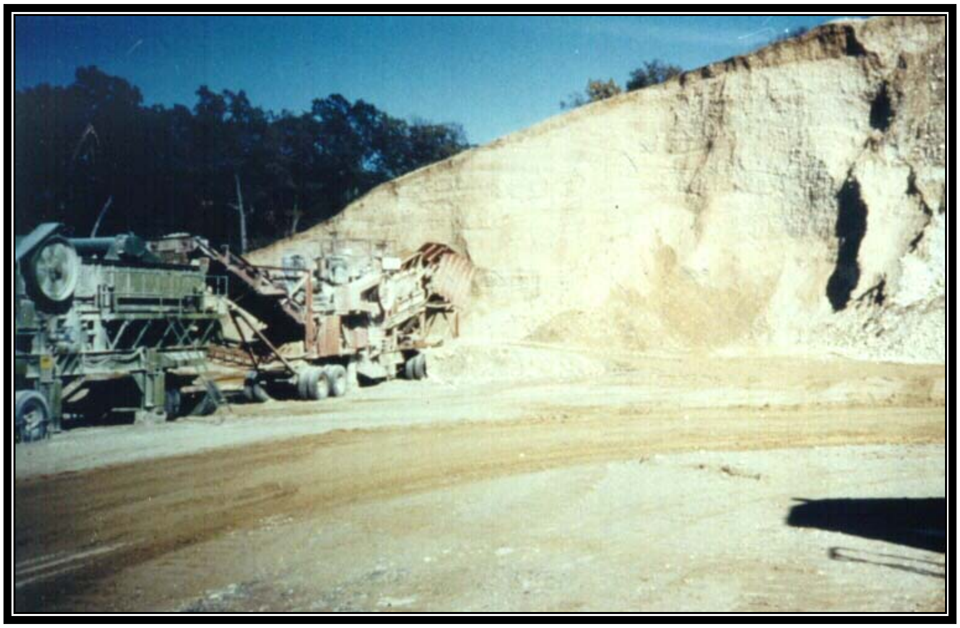


Figure 5-5. Sand and Gravel Excavation

Geologic variability in the deposit may sometimes affect sizing but more often causes a change in mineral integrity and physical properties. If a large variation exists, some products at later stages in the process may require separation.

Moisture variation in shot rock may also cause significant problems during processing. Shot-rock moisture is required to be monitored because significant changes in moisture almost always require changes in downstream processing.

CRUSHING

The first step of processing begins after the extraction from quarry or pit. Many of these steps also are common to recycled materials, clay, and other manufactured aggregates. The first stage in most operations is the reduction and sizing by crushing. Some operations, however, provide a step prior to crushing called scalping.

SCALPING

Scalping (Figure 5-6) most often is used to divert fines at a jaw primary crusher in order to improve crusher efficiency. In this way the very coarse portion is crushed and then recombined with the portion of crusher-run material before further processing. This first step may, however, be an excellent time to improve a deleterious problem. If a deleterious or fines problem exists in the finer fraction of crusher-run material (namely, clay, shale, finely weathered material, etc.) the fall-through of the scalping operation may be totally or partially diverted and wasted, or may be made into a product of lesser quality. In any case, only acceptable amounts, if any, should be returned back into the higher quality product. Consideration of process variables in this early stage may be very important.

Figure 5-6. Scalping

PRIMARY CRUSHING

In stone quarries or in very "boney" gravel pits, large material usually is reduced in size by either a jaw (Figure 5-7) or a gyratory crusher. Both types are compression crushers. Although economical, they have the tendency to create thin, elongated particles. Particle shapes sometimes may be a problem for Producers of hot mix asphalt. In some operations impact crushers are used for primary crushing, but they may have a slightly higher cost per ton. Impact crushers may upgrade poor-quality aggregate and increase separation, such as removal of rebar from concrete in recycling operations.

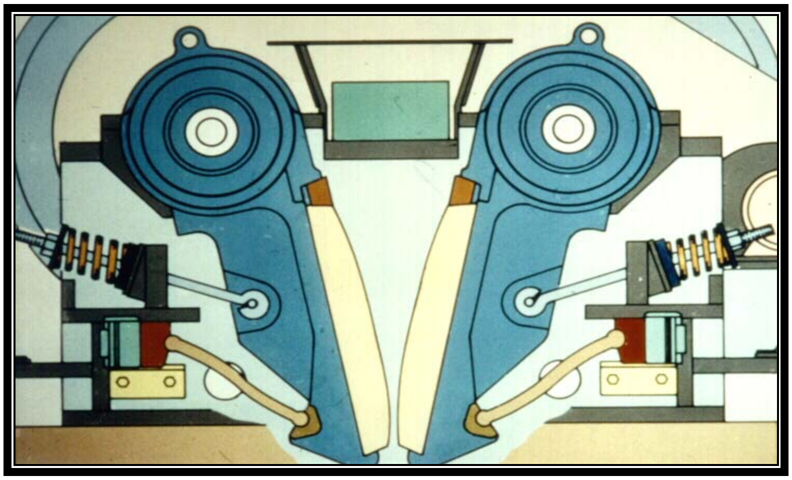


Figure 5-7. Jaw Crusher

After primary crushing/reduction the resulting aggregate generally is placed in a large "surge" pile where the aggregate may be fed into the secondary operation whenever convenient.

Care is always taken when building up and loading out surge piles, as this step may be a major source of segregation of material going to the secondary plant. Variation at this point may affect both mineral quality and gradation. Drawing from an inverted cone over a load-out tunnel works well after material has been deposited and left undisturbed to form the walls of the draw-down cone. If the need ever arises to consume the entire pile, care is taken to thoroughly mix the older material a little at a time with fresh product to make the surge as uniform as possible as the aggregate is being pushed into the tunnel. If the operation relies on end loaders to feed the secondary plant from the surge pile (Figure 5-8), the same care is taken to mix coarse with fine material from the outside to the inside of the pile.

Figure 5-8. Surge Pile

SECONDARY AND TERTIARY CRUSHING

Secondary and tertiary crushing, if necessary, are the final steps in reducing the material to a desired product size. Historically, cone and roll crushers were the most common choice crushers, but in recent years impact crushers are more widely used. These crushers also are sometimes used as primary crushers for fine-grained gravel deposits.

The cone crusher (a compression type) simply crushes the aggregate between the oscillating cone and the crusher wall (Figure 5-9). Clearance settings on this equipment are required to be checked and maintained as part of standard operating procedure.

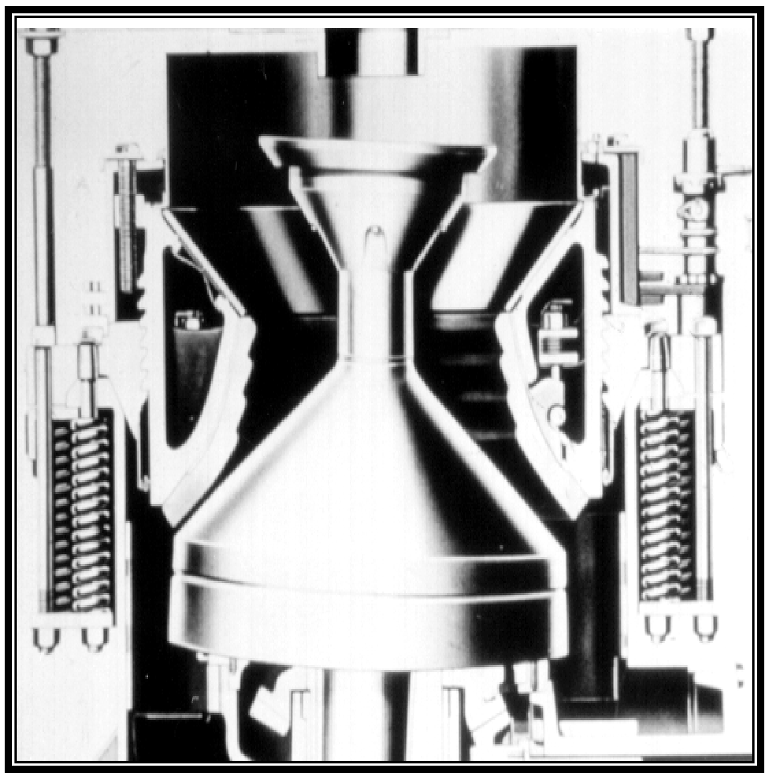


Figure 5-9. Cone Crusher

As with other compression crushers, the cone crusher yields a somewhat elongated and slivery particle shape. This may be minimized, however, by "choke" feeding the crusher. This technique will also make the shape and size more uniform. One way to choke feed is with a surge hopper and a controlled belt-feed to the cone crusher (Figure 5-10). Automatic level controls measure the head of the material over the top of the cone.

Figure 5-10. Crusher Feed System

A roller crusher (Figure 5-11) is another compression type crusher that simply breaks the material by pinching the aggregates. These types of crushers are often found in gravel operations. Roller crushers have constant maintenance problems and are prone to excessive wear. The rollers are required to be checked frequently to insure proper clearance and uniformity across each roller. Rebuilding and re-milling the roller is a standard operating procedure.

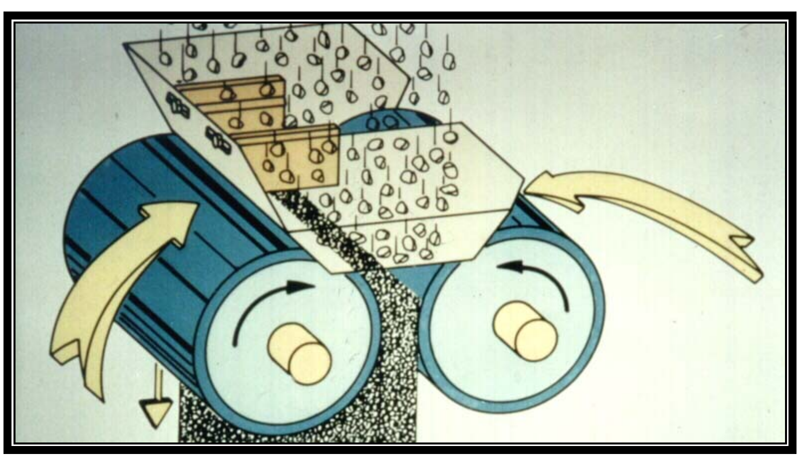


Figure 5-11. Roller Crusher

Impact crushers may be used as primary, secondary, or tertiary crushers. Despite having a somewhat higher operating cost than other crushers, they tend to produce a more uniform particle shape. Impact crushers usually will benefit the aggregate better than compression crushers, and they may generate more fines. Common types are the horizontal shaft (Figure 5-12), vertical shaft, and hammermill impactors.

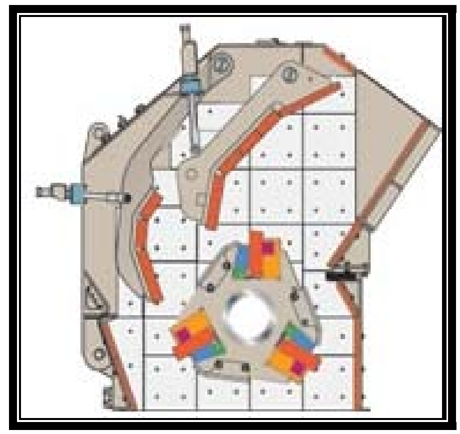


Figure 5-12. Horizontal Shaft Impactor

The horizontal shaft single or double rotor may aggressively handle large and odd-shaped material. Large horizontal impactors sometimes are used as primary crushers. Fracturing occurs at the same time by rock against rotor, rock against breaker bar, and rock on rock**.**

The vertical shaft impactor (Figure 5-13) is operated in rock against anvil, or rock against rock (through the installation of a rock shelf) modes. The Producer is required to decide carefully the mode best suited to the raw material.

Figure 5-13. Vertical Shaft Impactor

The hammermill impactor (Figure 5-14) provides excellent reduction and beneficiation through the impacting and shearing action of the hammers and grates; however, a large amount of fines is produced. This type of crusher is sometimes used in the manufacture of agricultural ground limestone.

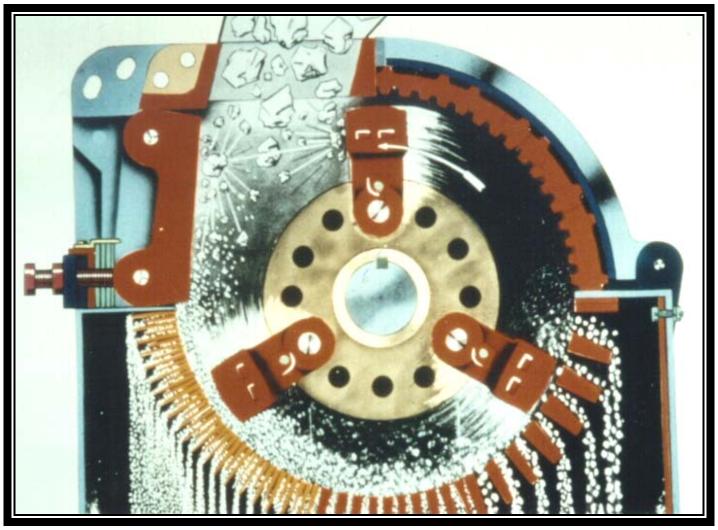


Figure 5-14. Hammermill Impactor

OTHER BENEFACTION

Other forms of benefaction for quality are available to the Producer. These include the log washer, heavy media separator, and attrition mill.

The log washer (Figure 5-15) commonly is used in wet operations to agitate and scrub clay and other objectionable fines from coarse aggregate. A Producer may need to use a log washer when rinsing screens do not remove these objectionable fines.

Figure 5-15. Log Washer

Heavy media separation is somewhat costly, but may be the only practical way for a Producer to meet quality requirements. This method works only when the undesirable material has a different specific gravity than the desirable material. The deleterious material is discarded after the media is separated for recycling.

Attrition mills are seldom used but remain an option when the deleterious particles are uniformly softer than the non-deleterious particles. The attrition mill abrades the deleterious particles into fines that may be screened out of the system.

SCREENING

Screening is another technique to control both quality and gradation of the aggregate product.

PRODUCT QUALITY

If deleterious material exists at undesirable levels after crushing and may be identified as being predominantly in one size range that is not needed for product size, the material may be screened out (namely, fines or top size). This step may occur between crushing so that an opportunity exists to recreate the same size downstream, if needed, to create a product. The screened-out lower-quality material may be used for a lower quality product or wasted if no use exists.

The rinse screen (Figure 5-16) is also commonly used. By processing the material over a screen that retains all of the product, the clay and deleterious fines may be rinsed away to make the product acceptable.

Figure 5-16. Rinse Screens

GRADATION CONTROL

The best technique for gradation control is screening (Figure 5-17). Screening may be done wet or dry, depending on the type of aggregate being processed and the degree of consistency required for each product.

Washing, for example, may be necessary to clean a concrete aggregate, but may not be needed for hot mix asphalt products, which may contain more fines. For gradation control alone, however, consistency sometimes may only be maintained by using wet screening. Gradation consistency is usually an overriding factor for a hot mix asphalt customer. Water volume and flow direction are critical in wet screening. Frequent checking of the gradation is a standard operating procedure.

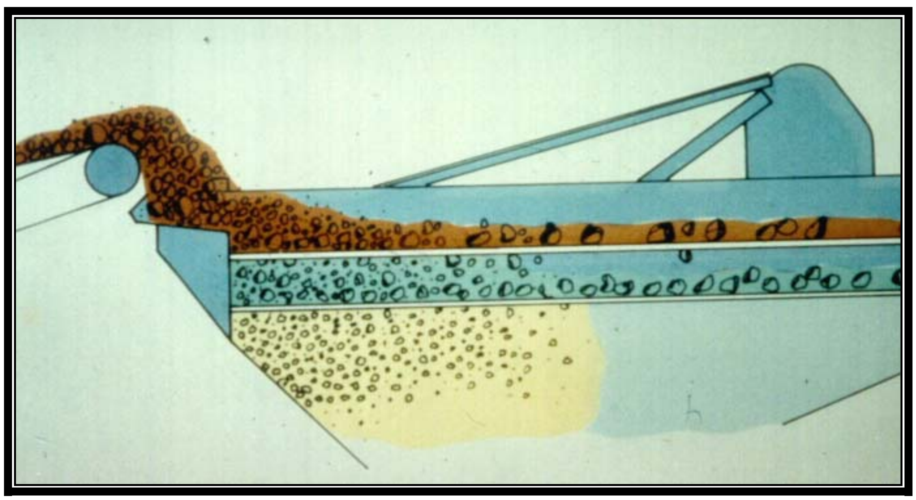


Figure 5-17. Screening

Dry screening is a slight misnomer because the material passing over the screen decks is wet, ranging from slightly damp to very wet, depending on conditions such as rain or subsurface moisture. Non-washed screening is a more accurate description of this screening process. High moisture is a concern because the wet aggregates may cause some material to become sticky and bind together, making the aggregate harder to separate. Furthermore, high-moisture conditions may cause binding of lower screen decks, causing override of the material rather than separation. If these conditions are encountered, the Producer may need to establish a balance between the moisture content of the incoming material and the feed rate through the screens. This balance is required to be made for each hour of operation. If reduced feed rates do not solve the problem or is too costly, washing or an additional screen area may be needed.

Sometimes screening variation is too great even under the most favorable of conditions. When this occurs the Producer is required to check that the equipment and the screen cloth are in good repair. The most common reason for high screening variability is the tendency to push too much material over a screen. The only way to maintain a bed of material thin enough for optimum efficiency is to provide enough screening to allow the desired rate of production. Standard operating procedures should reflect the maximum feed rate for the design of the plant.

For well-graded products having many sieves, (namely, #53s), gradation control may not be done without first separating the material into fractions. Separating the material into numerous small fractions and then back-blending at a set rate for each fraction may be necessary to control the gradation.

Frequent sampling, testing, and control charting are necessary for monitoring because aggregate gradation is subject to so many variables.

SAND PRODUCTION

Sand plays a critical role as a construction aggregate and deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers may be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing. These techniques are called particle exclusion. Whichever size the Producer decides to eliminate for quality reasons obviously also affects the sizing.

NATURAL SAND

Good quality natural sand is readily available in many areas and may be easy to obtain and process. As with the gravels that they often accompany, the sand deposits may not have been laid uniformly, meaning a potential change in quality and size is possible. In some deposits, sand found below the water table differs in fines content and quality from that found above the water table. Subsurface drilling, sampling, and testing is necessary to know to what degree and where these differences occur. Standard operating procedures in the Quality Control Plan should address the process if differences in size and quality are encountered, as a uniformly graded product of predictable quality is required to be maintained.

MANUFACTURED SAND

Because of the angularity, manufactured sand is very beneficial for use in hot mix asphalt where stability is critical. Many Indiana quarries are high in clay content and often a large amount of dust ends up in the feed stock for manufactured sand. Care is required to be taken to select the appropriate classification equipment that removes the necessary amount of minus No. 200, yet retains other fractions of the sand gradation that are needed. For some uses, particle shape is important. Particle shape is set primarily by the crushing operation for the coarse aggregate. Any changes in crushers or crushing techniques may affect the properties of the manufactured sand product and therefore affect the customer's use of the product.

PROCESSING

Very few sand products are produced by air classification or by direct non-washed screening. Most sands are produced with wash water and water classification. The key to all rinsing and water classifying systems is adequate delivery of water. Inadequate water supply and poor maintenance are the two most common reasons for inconsistent sand gradations.

The most common water classifier is a simple dewatering screw (Figure 5-18) which may make a single "cut" in gradation and float out a certain amount of fines. By altering the through-put and rate of water flow the cut point may be changed.

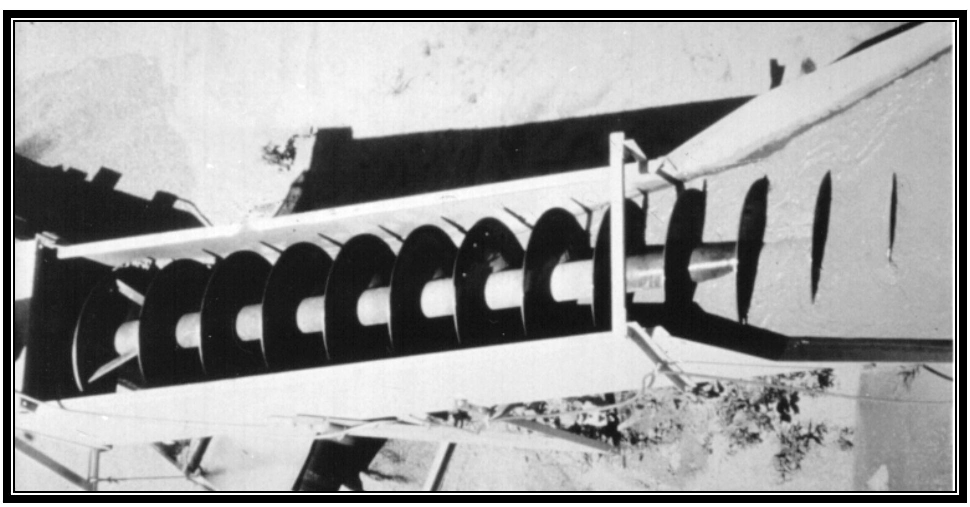


Figure 5-18. Dewatering Screw

A variation of the dewatering screw is the dewatering wheel (Figure 5-19). This device also is capable only of making a cut in the feed stock but may be more finely tuned and may be the better choice when trying to retain as much No. 50 and No. 100 material as possible.

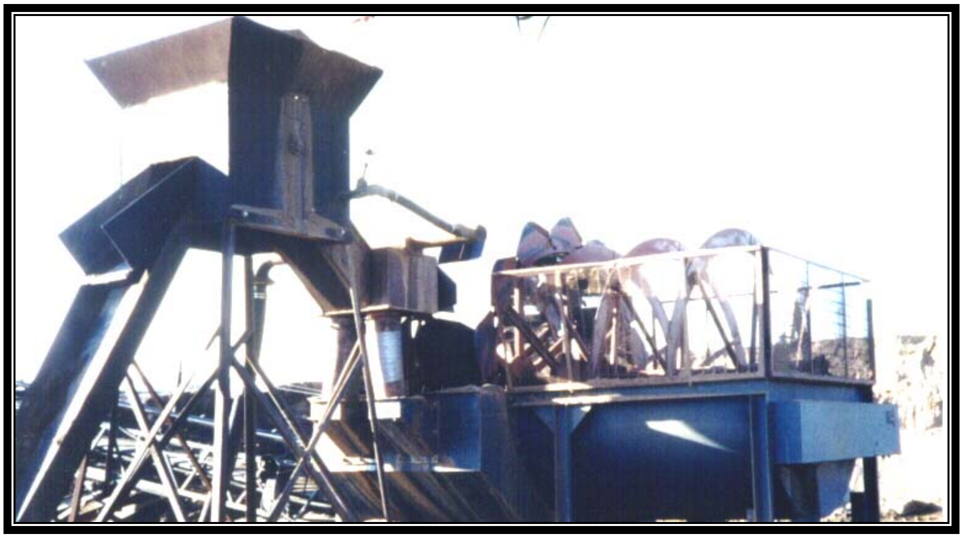


Figure 5-19. Dewatering Wheel

An even more sensitive method of cutting out fines is the wet cyclone (Figure 5-20). The sand slurry in the cyclone is spun at a prescribed velocity. Centrifugal force separates the coarser fraction from the water and fines which exit to the pond.

Figure 5-20. Wet Cyclone

Any of these techniques could conceivably be used with others in tandem or in tandem with rinse screens. The material could then be back-blended to create a desired product. A simpler and probably more cost effective way to control a sand gradation on multiple sieves is the rising current, multiple cell classifier (Figure 5-21). This equipment has numerous cells, each having varying water pressures that for different sizes of material. Any number of cells may then be combined to create the final product. With this type of system a high degree of process control is possible.

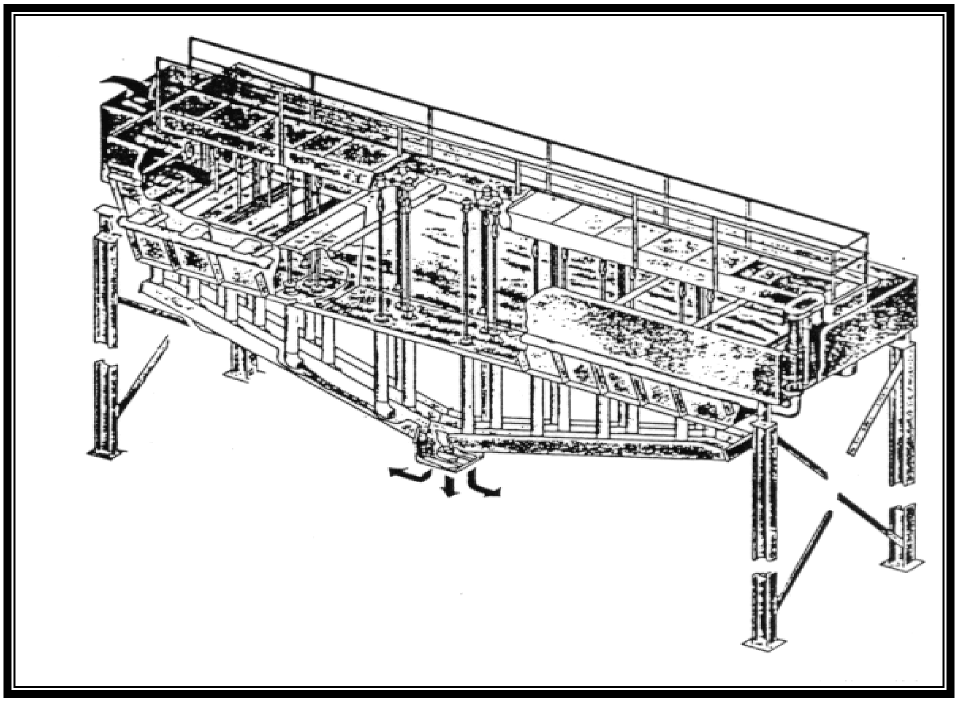


Figure 5-21. Multiple Cell Classifier

SEGREGATION

Product conformity and uniformity may be predicted if all of the inputs into the plant are measured, evaluated, and controlled. Whenever one rock is placed upon another rock, segregation may reduce the uniformity that the Producer so carefully has built into the product.

Segregation begins on the belt where fines vibrate to the bottom and coarse aggregate remains on the top as the material bounces across the idlers (Figure 5-22). At the end of the belt, if left un-deflected, the coarse particles are thrown out and away. Fine particles, on the other hand, tend to drop down or if wet even follow back underneath the conveyor. The greater the speed of the belt, the worse the segregation problem is. This is known as front-to-back segregation and may be addressed by the following methods:

1) Belt wipers underneath the head pulley that reduce carry back

2) Movable stackers kept near the top of the pile to reduce the spread

3) Mixing paddles or deflectors at the head pulley to keep the material together (Figure 5-23)

4) Wider belts at lower velocities to prevent segregation

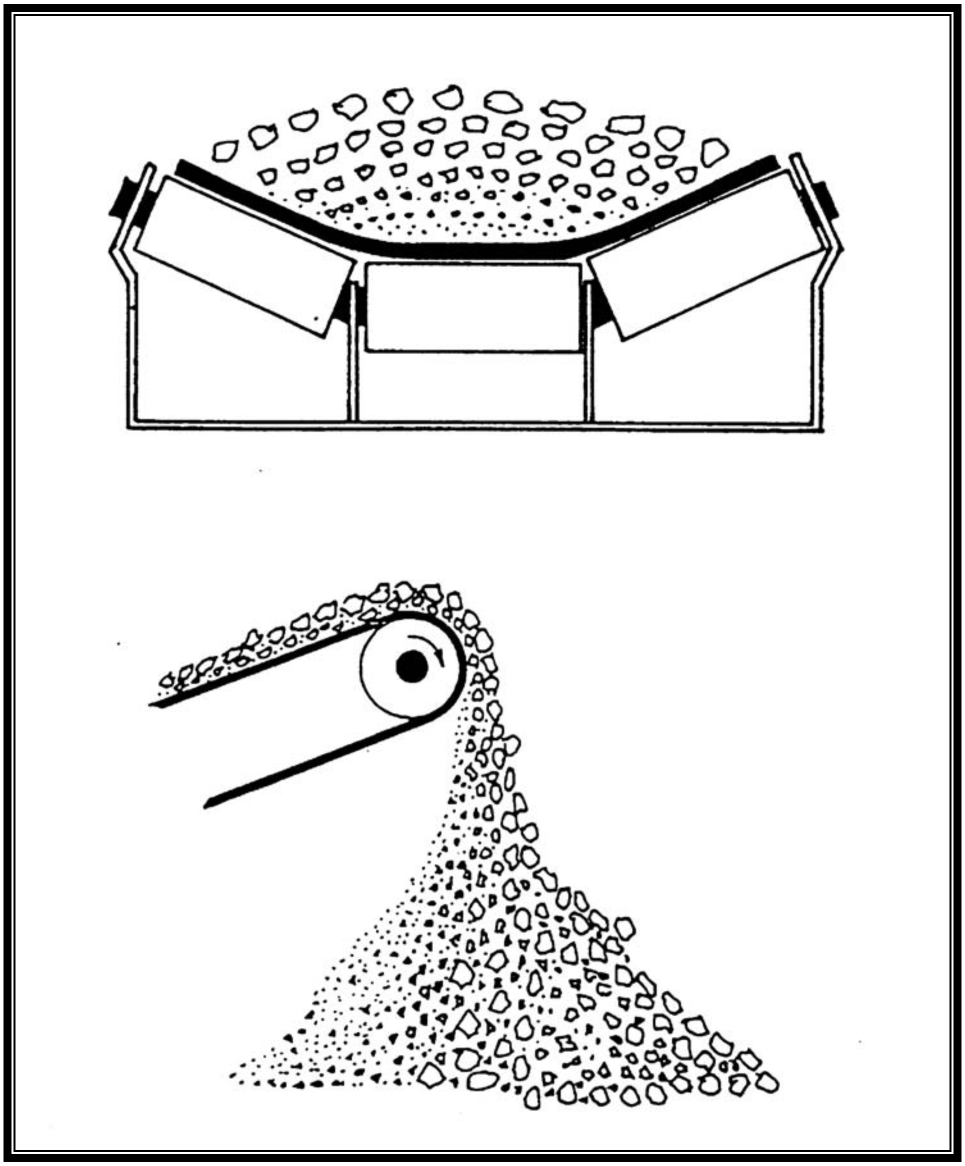


Figure 5-22. Belt Segregation

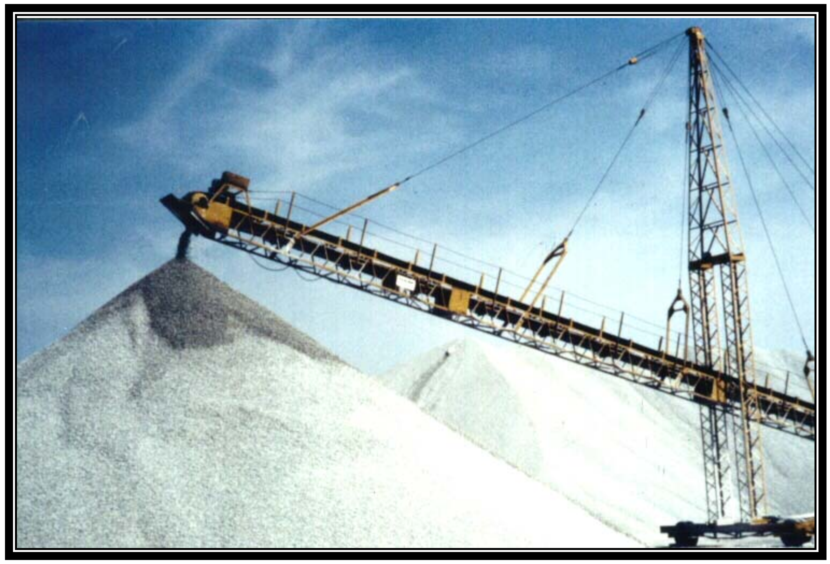


Figure 5-23. Adjustable Conveyor with Mixing Paddle

A second common type of segregation is "roll down," which occurs any time aggregate is piled so that large particles roll down the sloped side of the pile (Figure 5-24). The higher the pile, the worse this problem is. This type of segregation is very obvious in operations with high conical stockpiles, but also occurs in improperly loaded trucks. Keeping storage bins over half-full whenever possible improves the situation.

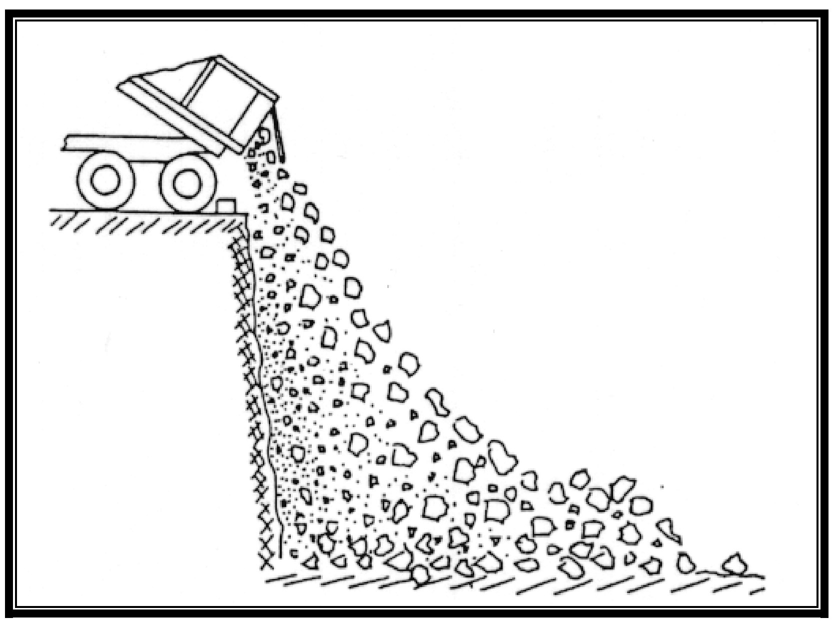


Figure 5-24. End Dump Segregation.

STOCKPILING AND HANDLING

Segregation is probably the greatest problem that occurs because of stockpiling and handling, but certainly other problems such as degradation and contamination may adversely affect product quality. Every possible precaution is required to be taken to protect the product quality from the point of manufacture to the point where the aggregate leaves the Producer's control.

CONE STOCKPILES

Although the cone stockpile is very common in the aggregate industry, two stockpile procedures may easily reduce product integrity. Roll-down segregation obviously occurs in full circle around the pile, and very high piles are difficult to adequately remix before shipping. These piles usually are being replenished with fresh material as old and new material is being removed, which keeps the product size in a state of continual change (Figure 5-25).

Figure 5-25. Material Added to Cone

In some cases the "front-to-back" segregation adds extra coarse material thrown forward and extra fines carried back for even greater variability. In addition, some piles are not fully retrieved for several years and the new product that is added to the old pile may even have different production targets (figure 5-26). Situations like these add up to serious problems for predicting gradation uniformity in the retrieved product.

Figure 5-26. Comingled Cone Piles

The final element of a cone pile that adds to the effects of both the roll-down and front-to-back phenomena is an excessively high drop from the end of a fixed conveyor to the top of the pile (Figure 5-27). This procedure should be avoided. Use of cone stockpiles should be kept to a minimum and used with extreme caution.

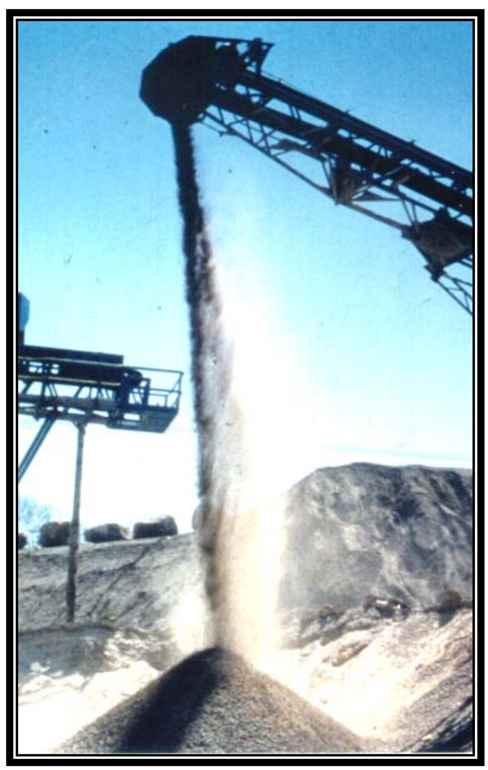


Figure 5-27. High Conveyor Drop

RADIAL STOCKPILES

A radial stacker (Figure 5-28) is a compromise solution for conveyor-built stockpiles, especially if kept less than 20 ft. The proper technique is to keep the end of the movable conveyor less than a meter from the top of the pile and raise the conveyor with the pile to the full height. Then the conveyor is moved horizontally with the pile in small increments. In this manner the pile is constructed at one end while the products are retrieved at the other end.

Figure 5-28. Radial Stacker

Although roll-down segregation does occur from the sides of the pile, a continual remixing of coarse and fine material occurs longitudinally as the pile advances. Proper retrieval may take care of the edges.

TRUCK BUILT STOCKPILES

If piles from the end of the product belts are thoroughly remixed then truck-built stockpiles (Figure 5-29) are capable of greatly minimizing segregation, if the trucks are loaded properly. The best truck-built stockpiles are those that are constructed one dump high with each dump placed against previously dumped material. This procedure, because of the low profile, reduces roll-down segregation and allows remixing during load out. However, these stockpiles require more space than the others mentioned. A technique that may help reduce the required area is to restock some dumps on top of other dumps with a large end loader operating from ground level. In this case, care is required to be taken to place the upper lift back from the edge far enough that a long sloped face is not created that would cause the same kind of roll-down problem that this type of pile is meant to eliminate.

Figure 5-29. Low Profile Truck Stockpiles

LAYERED STOCKPILES

A layered stockpile, if built correctly, may also greatly minimize segregation. Unfortunately these types of stockpiles are very difficult to build properly. Each layer is placed uniformly across the top of the pile in thin horizontal lifts. Care is required to be taken to keep the edge of each new lift set back from the edge of each previous lift so as not to create long sloped edges. This is best done with a large clam shell crane, which is slow and tedious, or with specially made equipment that may place the layers without being on the pile. A compromise is to allow hauling equipment on top of the pile; however, this procedure causes degradation of the product, and the pushing equipment may move the material over the edges causing severe segregation (Figure 5-30). Generally, these activities are poorly managed, and the stockpile takes on the shape of a ramp and spills over. These situations are very detrimental to product quality.

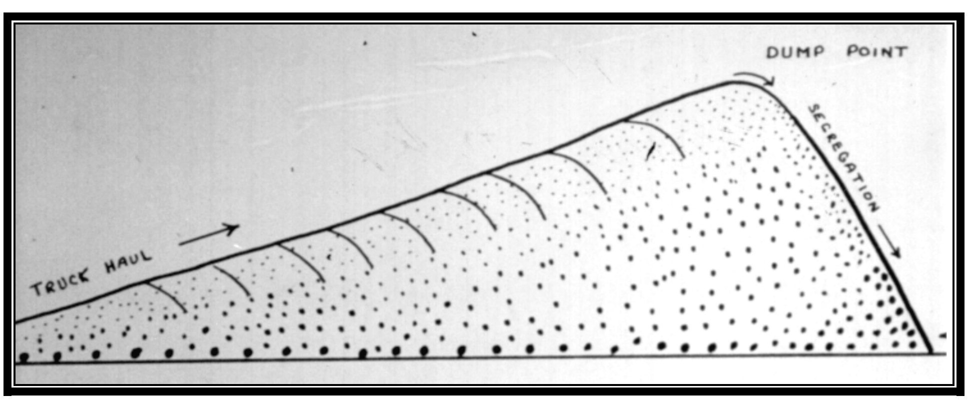


Figure 5-30. Ramp and End Dump

The Producer is required to write standard operating procedures on building stockpiles for each product and to educate all those involved in their responsibilities in the procedure. Most stockpiling problems are created because of inconsistent management. The procedures are required to become part of the Quality Control Plan. Illustrations at the end of this chapter indicate the different techniques that may be used for stockpiling and retrieving. The Segregation Index (S.I.) indicated with each example is a numerical index where the numbers are associated only with the other techniques and indicate greater segregation severity as they become higher.

DEGRADATION

Degradation or breakdown of the product is often caused by equipment running on top of the aggregate when the aggregate is being stockpiled (Figure 5-31). When this occurs, the degraded portion of the pile is required to be discarded before shipping. The difficulty lies in knowing where the "bad" material begins and ends. Extensive sampling and testing in these cases may be needed prior to shipping to determine what product is not good enough to ship. Degradation may also occur during retrieval where some of the lower portion of the pile is carelessly run over with equipment while loading out. A Producer is required to know which products tend to degrade with handling and make appropriate allowances. For example, many stone sands increase in minus No. 200 content each time they are loaded and moved. In some cases old stockpiles may degrade through weathering. Piles two years and older are required to be rechecked for gradation before shipping and possibly even for mineral quality.

Figure 5-31. Equipment on Stockpile

CONTAMINATION

Contamination (Figure 5-32) is usually the result of carelessness and poor housekeeping. In order to save space, stockpiles of different products are placed close together and as they grow in size they grow together. Equipment also may track dirt or other foreign matter into the product pile area. Old piles are subject to wind-blown fines over time and are required to be checked for this before shipping.

Figure 5-32. Comingled Stockpiles

RETRIEVAL

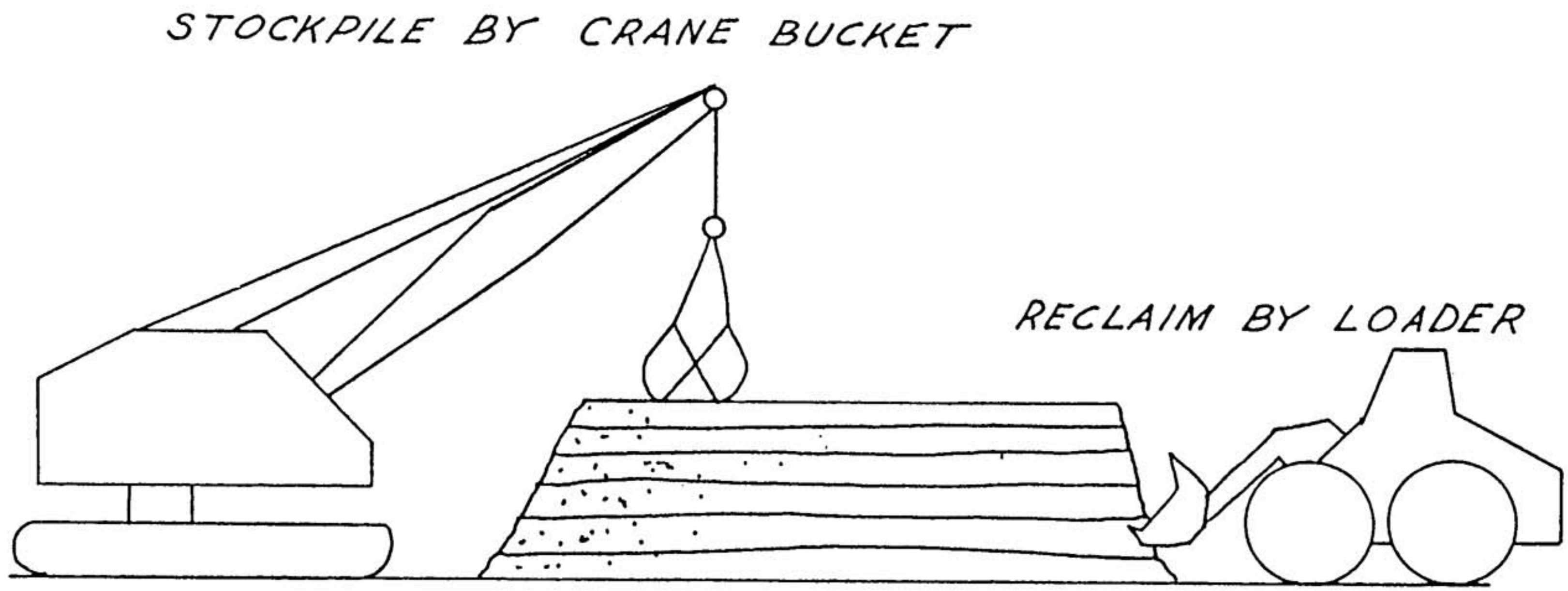
Retrieving material properly from a stockpile is just as important as building the stockpile properly (Figure 5-33). Truckers often force their way into the loading area, causing the loader operator to load from areas other than the working face. This practice is not allowed. Strict procedures for load out are required to be written, adhered to, and become routine as part of standard operating procedures. Loading from the outside of an un-worked pile for the sake of convenience may very quickly result in an unsatisfactory product.

Cone-shaped stockpiles are the most difficult to approach. Once retrieval has begun, no new material is added to the pile. To maintain a representative gradation, exactly one-half of the pile is required to be removed, the edges (coarse) folded into the center (fine), and the entire mass turned over and made into a level pad. The product is then ready for shipping. After shipping the first half of the pile, the procedure is required to be repeated for the second half. New material is required to be placed elsewhere in the meantime.

For radial or tent-shaped stockpiles, retrieval is required to begin at the oldest end while new material continues to be placed at the other end. The first entry into a new pile is handled as described above since the beginning of a radial pile is half-conical shaped. After a face has been established parallel to the stacking conveyor, continued mixing occurs in front of the load out face by pulling material from the center of the pile and mixing the material with the edges. The face is required to be kept as uniform as possible. At no time should new material be placed at the load out face.

For layered stockpiles more than one loader bucket high, remixing is necessary as the height of the pile and type of the product required. For low-profile truck-built stockpiles, only minor remixing is required when encountering the edges.

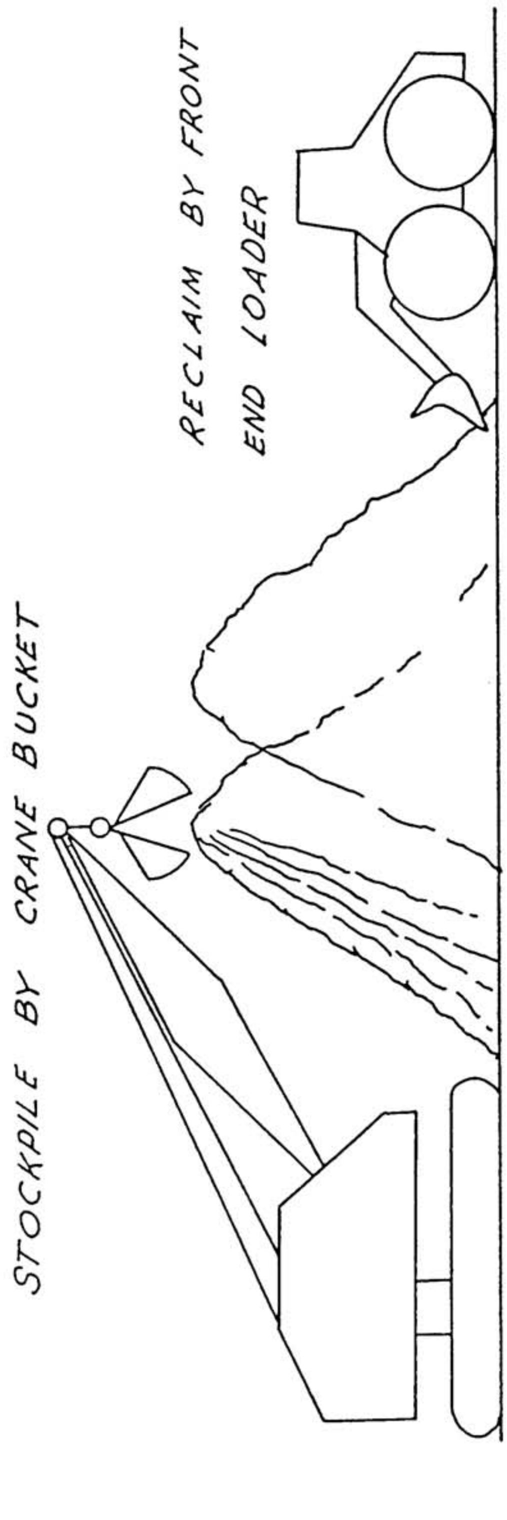
Figure 5-33. Retrieval from Stockpile



STOCKPILE METHOD #1

SPREADING AGGREGATE IN THIN LAYERS WITH CRANE BUCKET

BEST METHOD → SEGREGATION INDEX 1.35



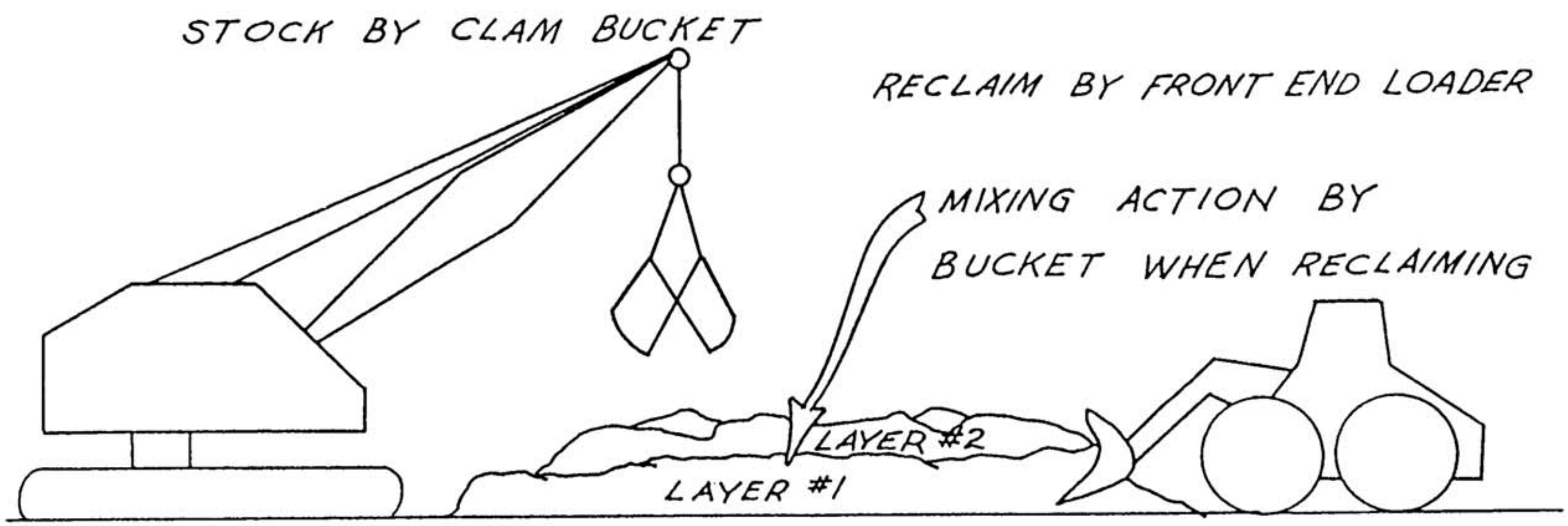
(COARSE GOES TO OUTSIDE OF CONE - FINES TO THE CENTER
RECLAIMING BY LOADER REMIXES COARSE AND FINE)

STOCKPILE METHOD #2

TWO CONES (APPROX. 750 TONS) CONSTRUCTED BY CRANE BUCKET

RECLAIM BY FRONT END LOADER

SEGREGATION INDEX - 16.48

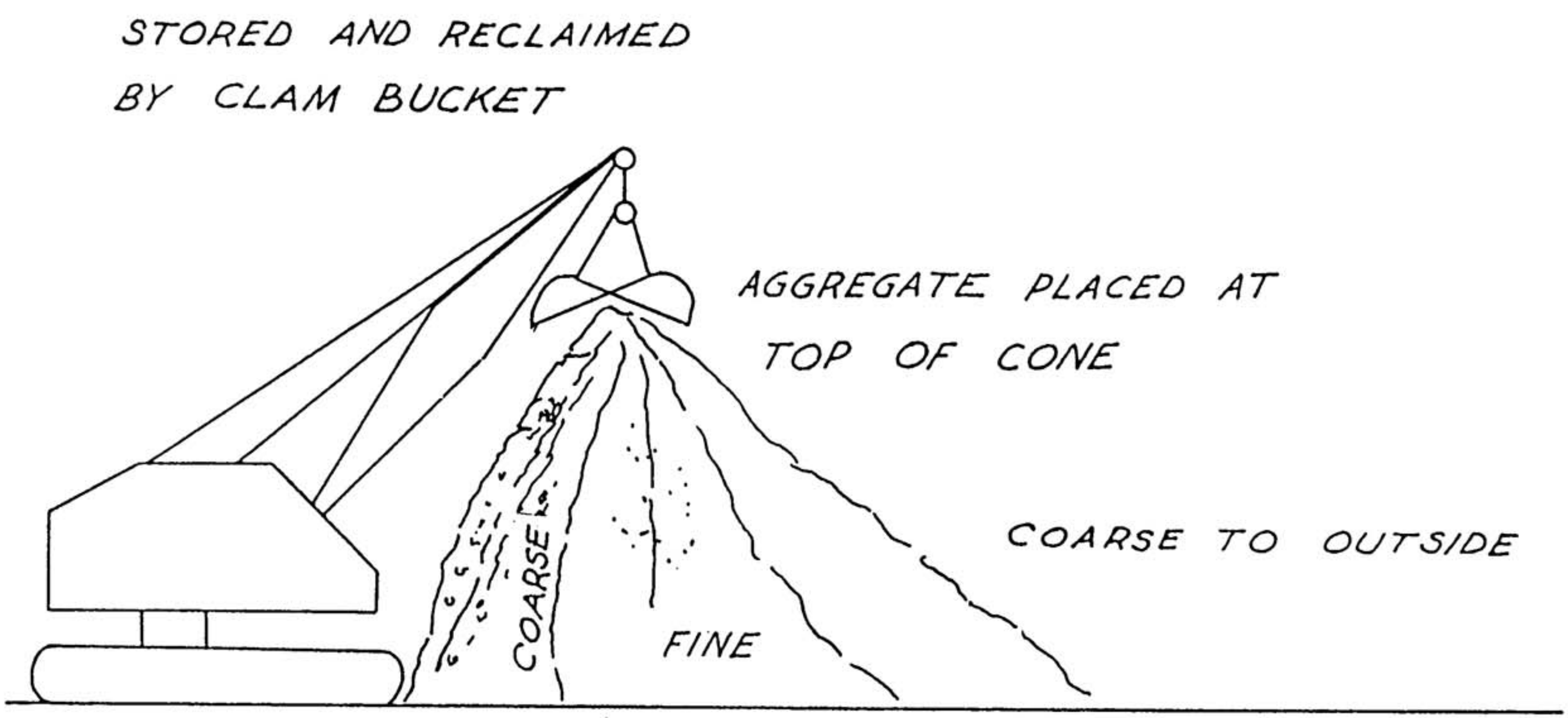


STOCKPILE METHOD #3

FLAT - LAYERED PILE BUILT WITH CLAM BUCKET

RECLAIM WITH FRONT END LOADER

SEGREGATION INDEX - 1.96

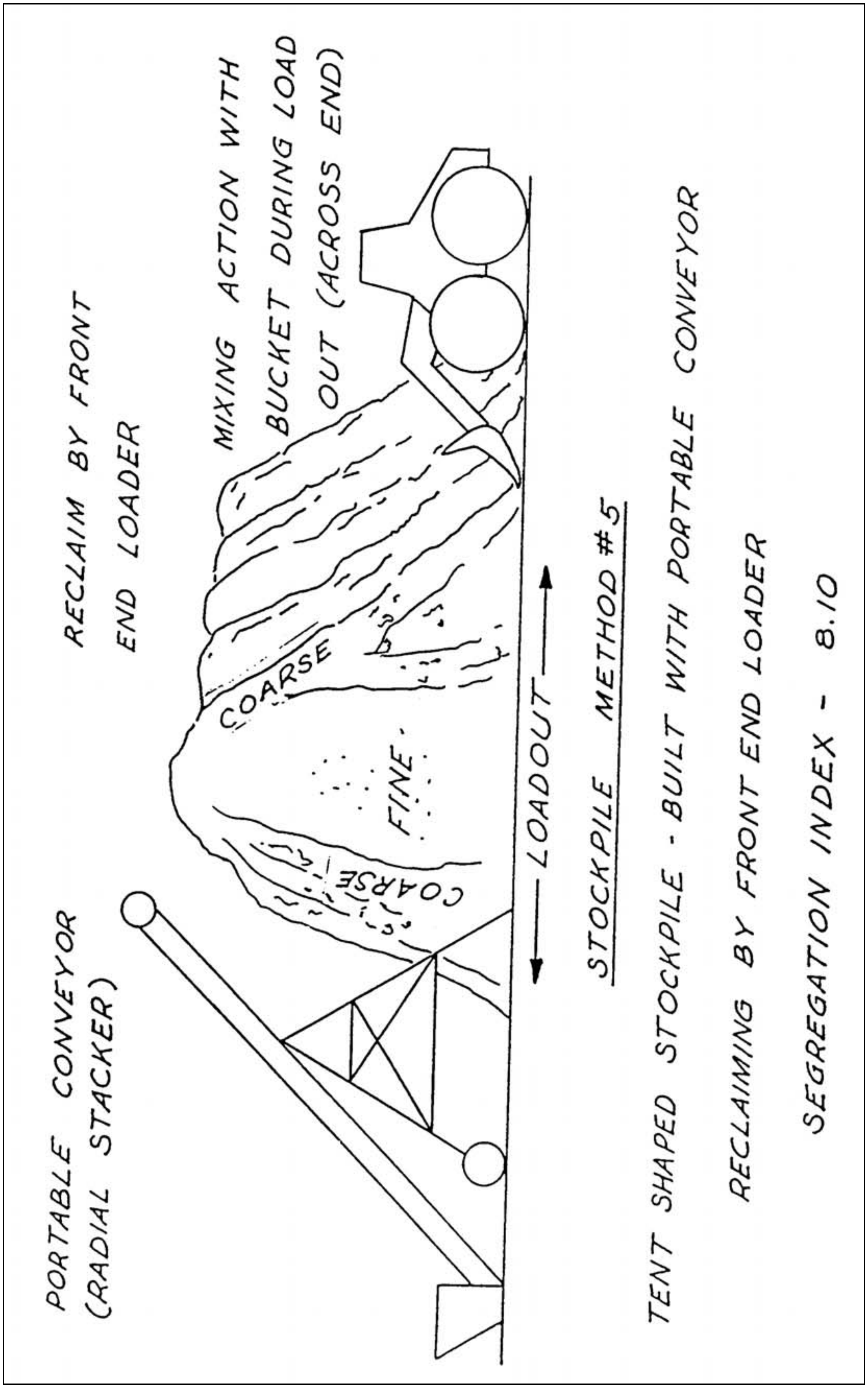


STOCKPILE METHOD #4

SINGLE CONE BUILT WITH CLAM BUCKET (APPROX 1,500 TONS)

RECLAIMED BY CLAM BUCKET IN HORIZONTAL LAYERS

SEGREGATION INDEX - 16.86 (WORST METHOD)

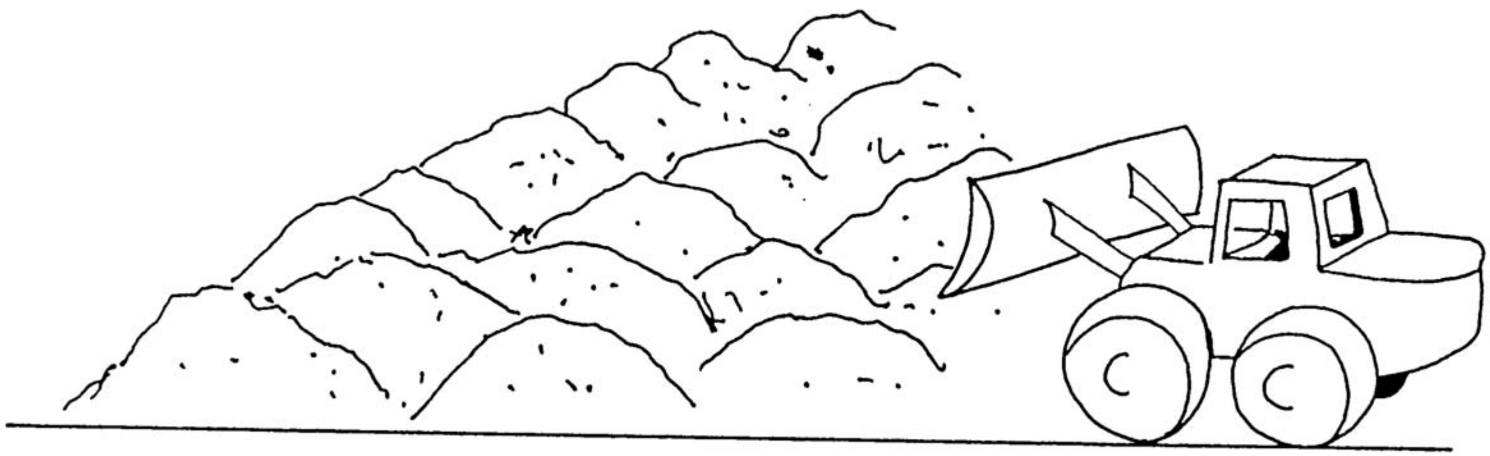

PORTABLE CONVEYOR
(RADIAL STACKER)
RECLAIM BY FRONT
END LOADER
MIXING ACTION WITH
BUCKET DURING LOAD
OUT (ACROSS END)
COARSE
FINE
COARSE
LOADOUT
STOCKPILE METHOD #5
TENT SHAPED STOCKPILE - BUILT WITH PORTABLE CONVEYOR
RECLAIMING BY FRONT END LOADER
SEGREGATION INDEX - 8.10

LIMITING FACTORS

HEIGHT OF LOADER BUCKET

LARGE AREA REQUIRED

STOCKED AND RECLAIMED
BY FRONT END LOADER

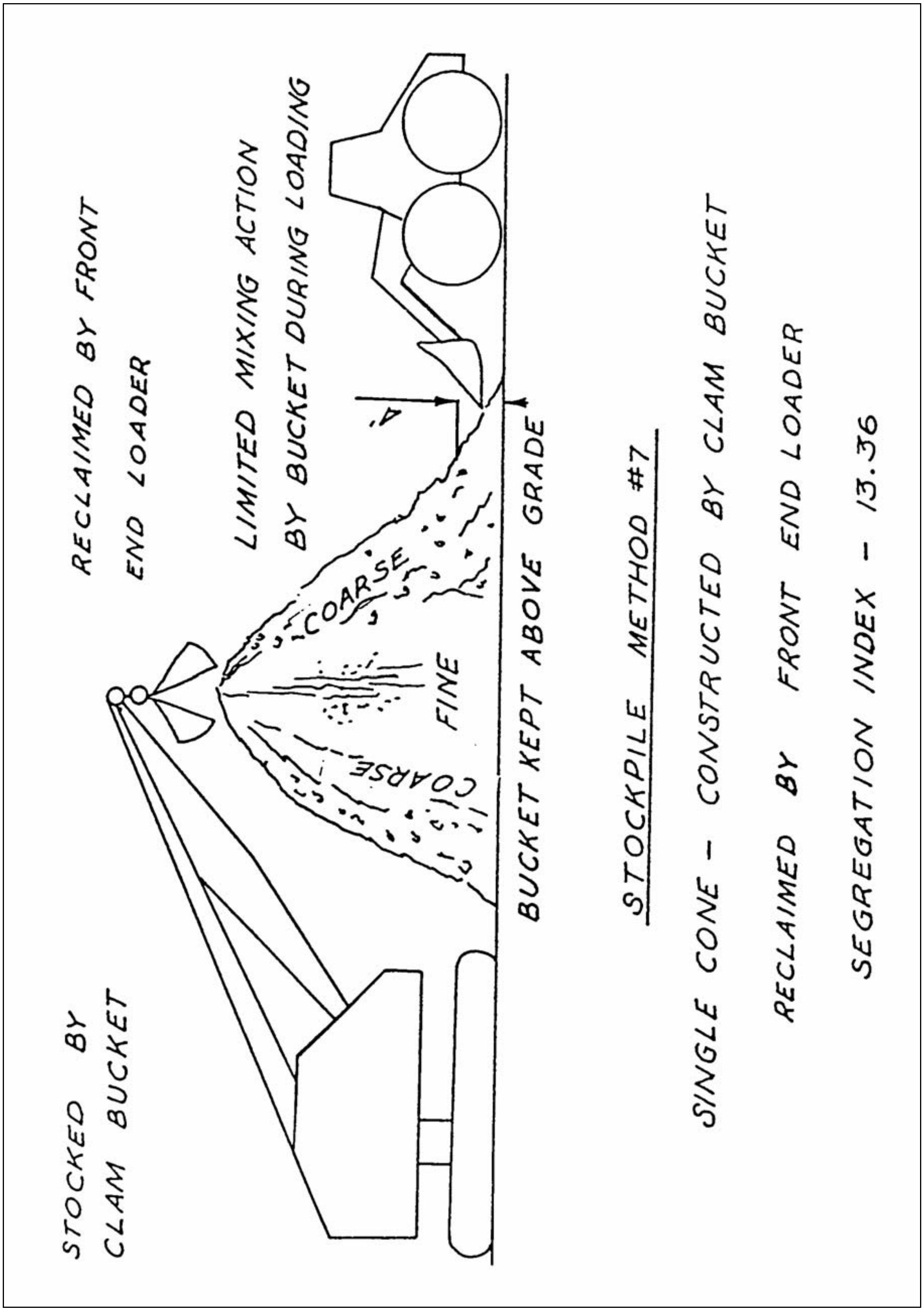


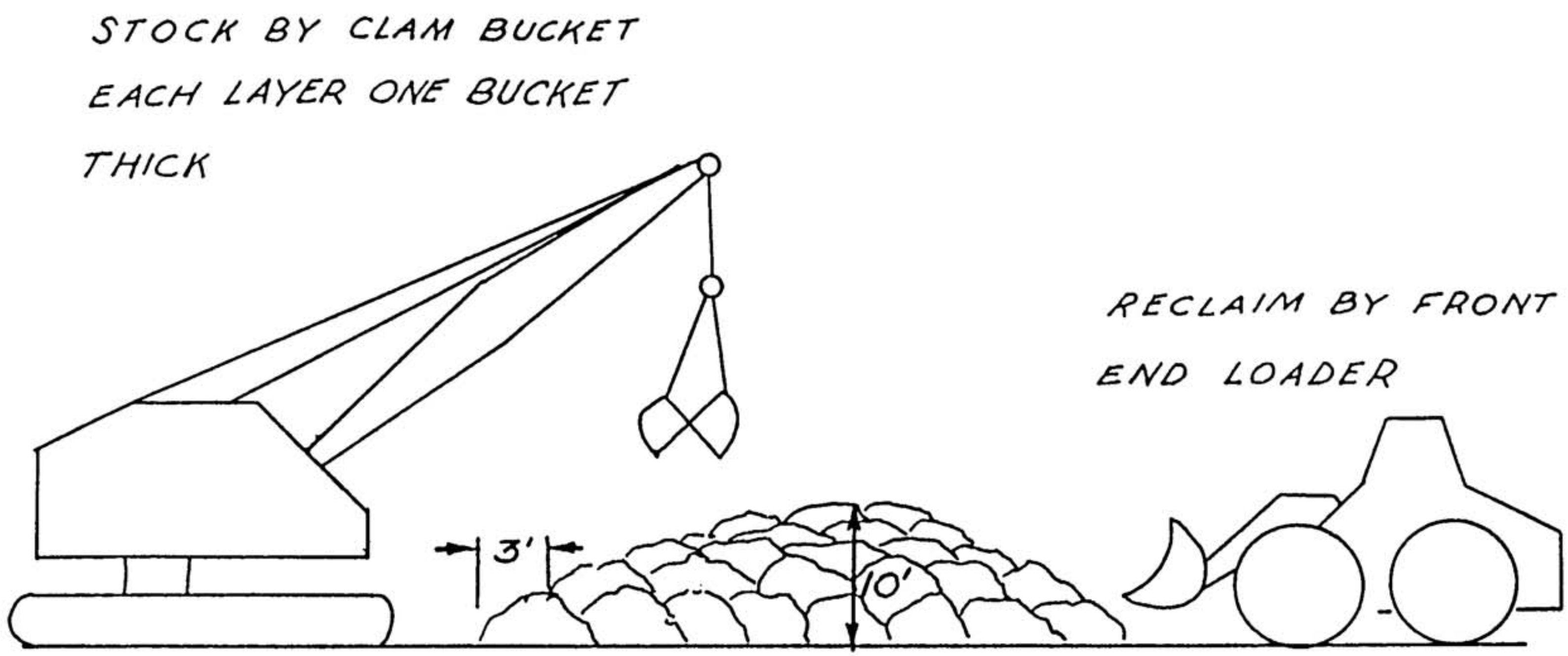
STOCKPILE METHOD #6

FLAT LAYERED CONSTRUCTED BY FRONT END LOADER

RECLAIMED BY FRONT END LOADER

SEGREGATION INDEX - 4.05


STOCKED BY
CLAM BUCKET
RECLAIMED BY FRONT
END LOADER
LIMITED MIXING ACTION
BY BUCKET DURING LOADING
COARSE
FINE
COARSE
BUCKET KEPT ABOVE GRADE
STOCKPILE METHOD #7
SINGLE CONE - CONSTRUCTED BY CLAM BUCKET
RECLAIMED BY FRONT END LOADER
SEGREGATION INDEX - 13.36



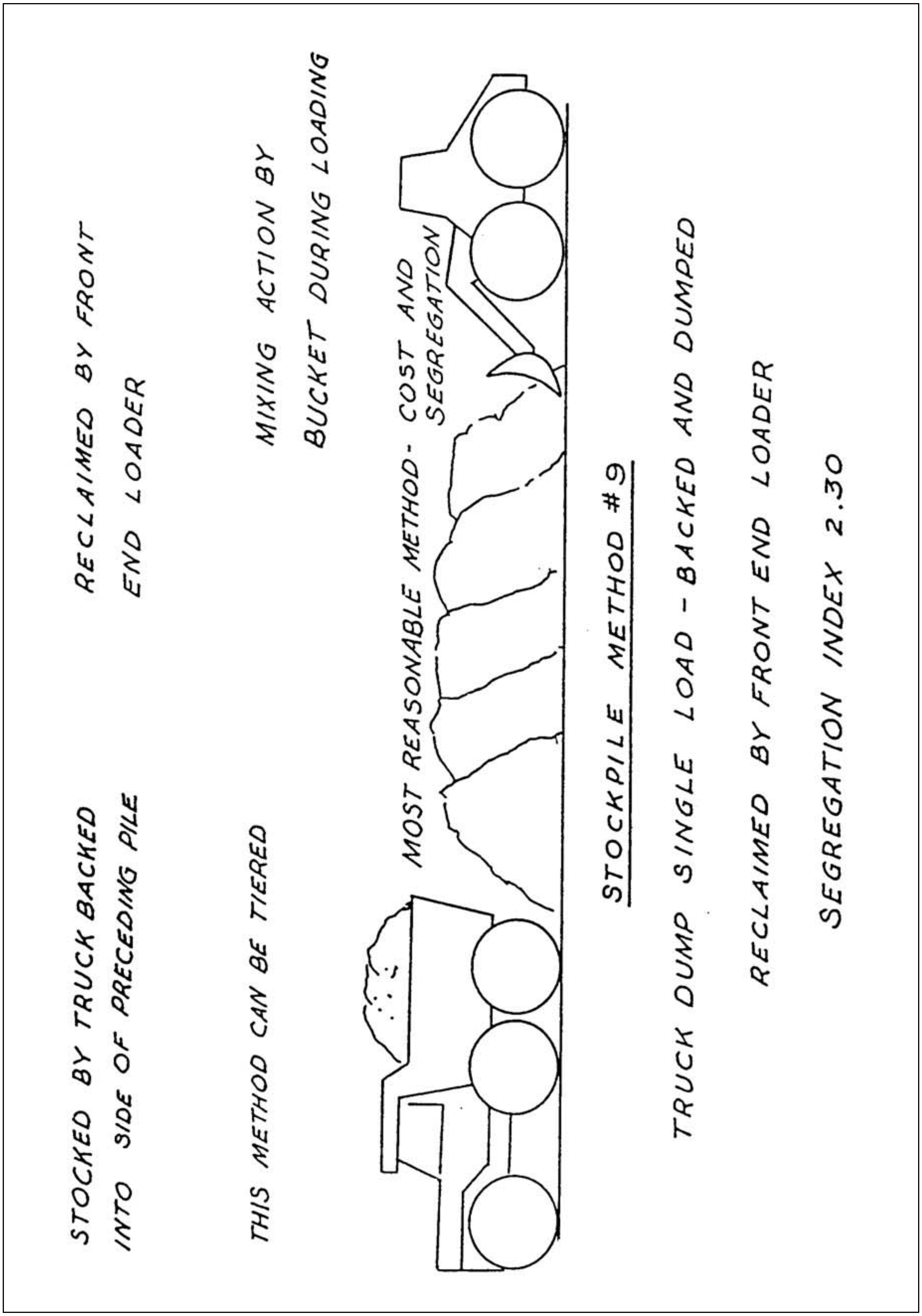
METHOD VERY SLOW AND EXPENSIVE
SET BACK OF 3 FT BETWEEN LAYERS

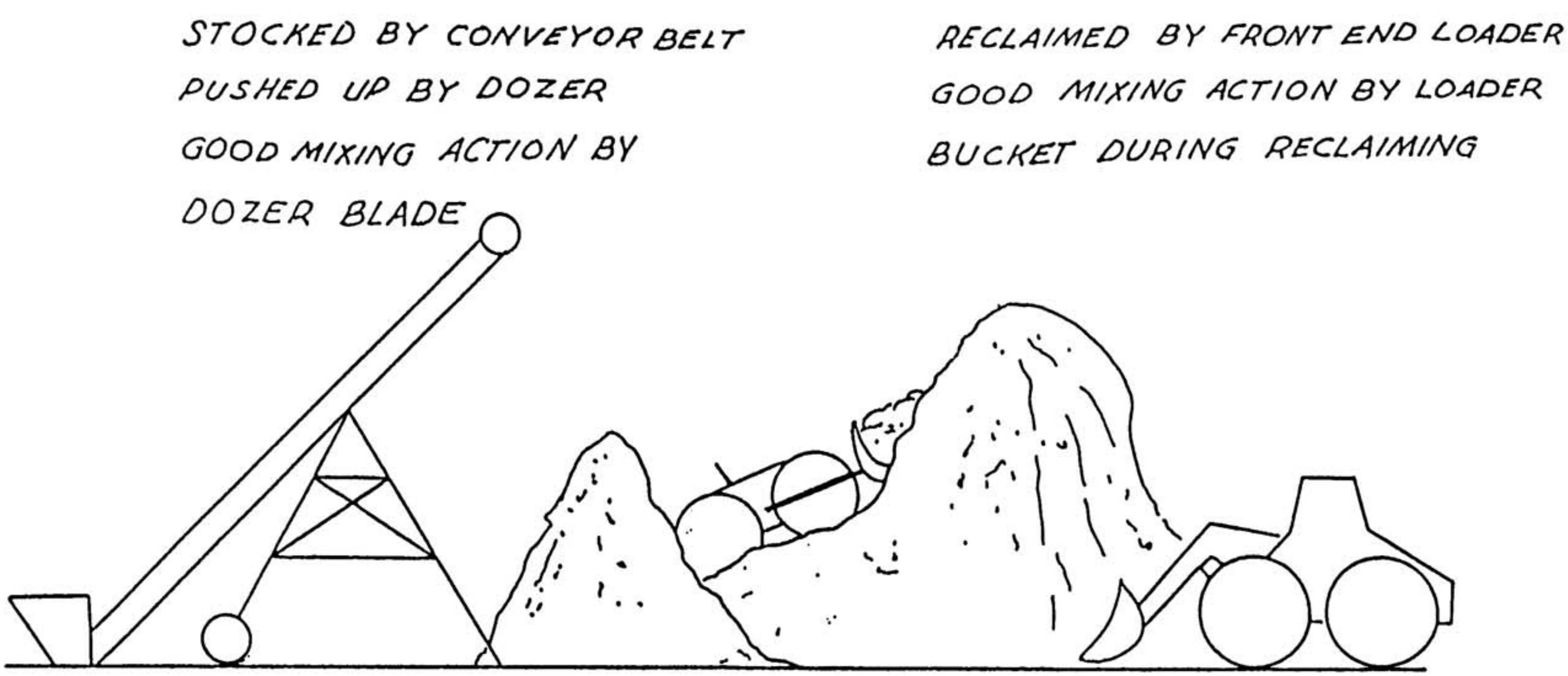
STOCKPILE METHOD #8

TIERED (BERMED) BY CLAM BUCKET

RECLAIMED BY FRONT END LOADER

SEGREGATION INDEX - 7.37


STOCKED BY TRUCK BACKED INTO SIDE OF PRECEDING PILE
RECLAIMED BY FRONT END LOADER
THIS METHOD CAN BE TIERED
MIXING ACTION BY BUCKET DURING LOADING
MOST REASONABLE METHOD - COST AND SEGREGATION
STOCKPILE METHOD #9
TRUCK DUMP SINGLE LOAD - BACKED AND DUMPED
RECLAIMED BY FRONT END LOADER
SEGREGATION INDEX 2.30



STOCKPILE METHOD #10

RAMP BUILT WITH PNEUMATIC - TIRED BULLDOZER

RECLAIMED WITH FRONT END LOADER

SEGREGATION INDEX 1.59