Mineral aggregate roof surfacing

Tibbetts, D. C.; Baker, M. C.

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Mineral Aggregate Roof Surfacing

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D.C. Tibbetts and M.C. Baker

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Roofs are often more exposed to climatic conditions than the other exterior elements of a building. With few exceptions, roof membranes are not protected by adjoining buildings and are generally fully exposed to wind, precipitation, temperature variations and sunlight. The final waterproof coating of a built-up roofing membrane is usually a comparatively thin layer of bitumen. To give it adequate waterproofing and wearing qualities some additional surface protection is necessary. A possible exception is clay-stabilized asphalt emulsion, but the weathering qualities of even this material are much improved by a surface treatment in the form of an applied reflective coating.

Suitable surfacing will protect bitumen from sunlight and prevent excessive surface temperatures. Paint treatments, aluminum foil, tile or concrete surfacing, and mineral aggregate have been used for this purpose. Paint treatments can provide good protection and reflection of solar radiation, but have a definite, usually short, life. Aluminum foil can give excellent protection, and has been successfully used as a surfacing for some proprietary felt roofings in other countries. Tile and concrete are often used when a traffic surface is required and give excellent protection to the membrane when proper allowance is made for structural and thermal movement and for drainage. Asphalt shingles and prepared roofing have a protective layer of fine mineral material, which is factory applied. Low pitched and flat roofs in Canada with bituminous builtup roof coverings are usually protected by a layer of coarse mineral aggregate type of protective roof surfacing, commonly referred to as roofing gravel.

Function

Mineral aggregate surfacing is applied to built-up roofing to protect the top coating of bitumen from direct sunlight and to reflect solar radiation. It reduces the maximum surface temperature, the seasonal range of temperatures and the short-time fluctuations at the black surface. It thus inhibits weathering of the bitumen and bituminous felts of the roofing membrane.

A heavy layer of mineral aggregate will reduce fire hazard from flying brands and provide ballast for the membrane against wind uplift. It offers limited protection against abrasion from wind and weather, and helps to prevent flow of bitumen on slopes in hot weather. For industrial areas it gives some protection against the airborne waste products from industrial processes. Aggregate also protects the membrane against casual foot traffic. Some of these functions will be discussed in more detail.

Sunlight and Surface Temperatures

Many roofs are exposed to the sun's rays from sunrise to sunset and much of the sunlight strikes the roof surfaces at a steep angle. It was shown in **CBD 41** that a dark roof with an unobstructed view of the sky can attain a surface temperature as high as 190°F in any part of Canada. Reflected radiation from adjacent surfaces can raise the surface temperature above that attained by direct radiation. The maximum surface temperature of a dark horizontal roof situated close to the south wall of a very high building can be as high as 230°F near noon in midsummer.

Colour has a considerable effect on the fraction of solar irradiation absorbed by a surface. White absorbs about 40 per cent; dark green, brown or black surfaces absorb about 90 per cent. The maximum temperature of a white roof surface would be about 130°F, as compared with 190°F for a black roof, a difference of 60 F deg.

The disintegration of bituminous material under the action of sunlight is generally considered to be a type of photo-oxidation. Watersoluble and volatile products are formed during chemical changes brought about by the ultraviolet rays of the sun in the presence of oxygen. The actual chemical change may be an extremely complex reaction related to the nature and source of the bitumen. As it takes place more readily at higher temperatures, any treatment that will keep temperatures low is desirable.

Temperature Variations

The high surface temperatures on roofing membranes in summer can accelerate the degradation of the bitumen, but the range of temperatures from summer to winter and from day to night is also important. These temperature variations can contribute to the breakdown of the bitumens, and may also cause large thermal movements of the total membrane. **CBD 47** indicated that the minimum surface temperature of the black surface of an insulated roof may be 10 deg colder than the ambient air temperature. The limits of surface temperatures on black insulated roofs in some areas of Canada can be as wide as -50 and 230°F.

The calculated values for outer surface temperatures of buildings have been corroborated by measurements made on buildings in Ottawa and elsewhere. As an example, temperature measurements for a one-month period on both black and white roof surfaces in Halifax indicated the following temperature ranges:

1. Air temperatures 46 to 80°F for a difference of 34 F deg.
2. White surface temperatures 42 to 124°F for a difference of 82 F deg.
3. Black surface temperatures 42 to 145°F for a difference of 103 F deg.

[It might be noted that the month of July chosen for making the measurements was the coldest for Halifax in 74 years.]

As expected, the black surface was warmer than the white at maximum daytime temperatures and both were warmer than the air temperature. At night the black surface was colder than the white at minimum temperatures, and both were colder than the air temperature. It is interesting to note the 120 F deg range in air temperature in Halifax, from a maximum of 99°F in July 1912 to a minimum of -21°F in February 1922. This 10-year period is shorter than that for which built-up roofing membranes are expected to perform satisfactorily. Such a range of air temperatures over the expected life of a dark roof can produce a membrane surface temperature range of over 200°F, with an expected temperature of 25 to 60 F deg less for a white roof.

In addition to the seasonal variation described above, the short-time variations in temperature during both winter and summer may frequently be as much as 100 F deg in some parts of Canada, unless aggregate or other surfacing is used to reduce the fluctuations.

Fire Hazard

The resistances of roof structures and materials to internal fires are generally well known, as judged and determined by standard fire tests. It is necessary that the roof covering should not contribute fuel to such internal fires. As the structural roof will normally provide resistance to internal fires, the main function of the roof covering in relation to fire is to reduce the risk of spread from neighbouring buildings. It is also important that the covering should not spread flame rapidly or produce flying brands to endanger adjoining roofs. Control in Canada has been effected by using roofs that have proved satisfactory in use.

Test methods for the fire resistance of roof covering materials (UL.790) were prepared in the U.S. in 1958 by the Underwriters' Laboratories Inc., who tested, classified and listed a number of types of built-up roofing. The resistance of bituminous materials is generally poor, but a built-up roof with aggregate surface would be expected to receive Class A or Class B Underwriters' classifications designated by some building codes as fire-retardant roofs. Class A refers to roof coverings effective against severe fire exposures. Under such exposure, roof coverings of this class are not readily flammable and do not spread fire, afford a fairly high degree of fire protection to the deck, do not slip from position, possess no flying brand hazard and do not require frequent repairs to maintain their fire resistive properties. Class B roofings are effective against moderate fire exposures, and Class C roofings afford a slight degree of fire protection.

Wind Effects

Wind pressures on buildings were discussed in **CBD 34**, and it was noted that the roof is usually the critical area in the wind design of low buildings. Particular attention must be paid to anchorage details because of the suction condition that may prevail over most if not all of the roof. In addition, high local suctions can develop with certain shapes of buildings or roofs, and with certain wind angles. Local suctions are generally most serious for a wind at an angle of 45 deg to the side of the building. Model studies have indicated small areas of local uplift from two to five times the normal uplift, at or near corners projecting into the wind.

Some buildings may require parapets to reduce these uplift forces on the roof, and attention to flashing details is obviously always of great importance if roof blow-offs are to be avoided. Aggregate surfacing will provide additional weight to resist the uplift forces. The aggregate also protects the membrane from the abrasive effect of particles carried by the wind, either as fine grit or as larger particles from erosion or poor embedment of aggregate on adjacent roofs.

Corrosive Products

Roof membranes can be damaged by airborne waste products from industrial and domestic furnaces and industrial process equipment. Heavy dews are common on roofs, and pollutants deposited on the roof surfaces may form acids that can cause considerable damage to metal flashings and exposed organic felts. This process may continue until rain washes the waste into the roof drains. Mineral aggregate surfacing provides some protection for the membrane.

Traffic

Where regular foot or other traffic may occur over roofs, adequate provision must be made for it. This can be accomplished by the use of wood, concrete or tile trafficways, or complete traffic surfacing where warranted. Mineral aggregate surfacing does give some protection for the membrane against casual foot traffic during and after construction of the building. It cannot be expected to give protection against workmen installing mechanical or other equipment over the roofing.

Properties Required

To perform satisfactorily an aggregate must be clean and dry, of sufficient size and weight to embed properly in the flood coat of bitumen and resist blow-off by high winds or wash-off by heavy rain. Aggregate must be so graded as to permit proper nesting and filling of voids between individual particles and to provide a complete and continuous membrane. Complete coverage must be maintained over all parts of the roof if satisfactory service is to be expected.

An aggregate should be hard enough to resist abrasion and frost action, but not so brittle that it encourages fracture and disintegration.

The usual aggregates are crushed stone and gravel, or crushed air-cooled blast furnace slag. Slag aggregate is opaque and angular. Its alkaline surfaces have a greater affinity for bituminous material than for water, with resultant good adherence of the bitument to the aggregate.

Aggregate should be uniformly graded in particle size, and a sieve analysis requirement is included in ASTM specification D1863-64, as in Table I. Other physical property requirements of this specification are shown in Table II. Methods of test to determine these physical properties are also specified to ensure that light gravel, which will easily blow off, is not used. Fine aggregate fractions (less than 200 mesh as indicated by sieve analysis) are undesirable even at 0.5 per cent, but 0.25 per cent is normally acceptable if it does not adhere to the surface of the aggregate. Hardness is of importance if the aggregate is susceptible to dusting.

Table I. Sieve Analysis Requirements

Passing Sieve (Inch)	Retained on Sieve (Inch)	Percentage of Sample
-	1	-
1	3/4	0
3/4	1/3	0 to 10
1/2	3/8	20 to 60
3/8	1/4	25 to 70
1/4	1/8	0 to 15
1/8	-	0 to 5

Table II. Physical Property Requirements

Moisture, maximum, per cent:	
Crushed stone and gravel	0.5
Crushed roofing slag	5.0
Unit Weight(loose), min Ib/cu ft	60.0
Dust, maximum, per cent	0.5
Hardness, maximum, percentage	

passing a No. 6(3.36 mm) sieve	20.0

Clay, loam, sand, organic matter, chemicals or other foreign substances, and frozen material should not be permitted in roofing aggregate. The practice of using what is available rather than what is suitable should be discontinued. Requirements in specifications should be detailed, and such general references as "aggregate shall be 1/4 to 5/8 inch in size, clean and free from dust and foreign matter" should be avoided. Various interpretations can be made from such references.

It is generally agreed that aggregate should be opaque to ultraviolet light, although no standards-making body has set any limits of translucency, and there is little or no information to indicate the significance of ultraviolet light translucency. Dolomite and marble chips, which make attractive white aggregate for roofs, are claimed by some sources to be poor in this regard. It is thought that small individual pieces can be translucent, permitting light to penetrate to the bitumen and accelerate the weathering process. Oxidation of the bituminous coating in which aggregate is embedded causes hardening and cracking, and this weakens the bond between coating and aggregate, allowing the aggregate to be more easily blown or washed away. White aggregate is desirable in relation to surface temperatures and a good compromise for its use might be a double surfacing procedure. The first surfacing could use harder and darker aggregate, and the final surfacing could be a softer and light coloured or white aggregate selected principally for its colour.

Application

As the finish layer of bitumen is the first barrier against moisture penetration of the roofing membrane it must be applied exceptionally carefully. The bitumen must be continuous and give complete coverage of the felts, with no laps penetrating the coating. This is its principal function and embedment of the aggregate is secondary. The aggregate is applied to protect and maintain the top coating and is a separate function from the waterproofing.

Job organization should include adequate protection of the aggregate against moisture and contaminants until it is ready for use on the roof. The recommended method is to move dry aggregate from the ground storage to the roof for application at the rate at which it is being used, with no stockpiling on the roof. If piled on the roof at all, it should be in small piles or rows, and should never be left unused overnight or over a weekend. When saturated with water or snow it is useless for its intended purpose until properly dry; if it lies over roofing felts the moisture may penetrate the felts and ruin the membrane. There is less chance of skipped areas, which are fairly common with some methods of placing, if aggregate surfacing is applied in two separate operations. This is particularly true if loose gravel is swept back after the first application. It may even be convenient to withhold the second surfacing until other trades have finished working over the roof, when minor damage can be repaired before the final application.

The roof must be completely dry so that there is no danger of trapping moisture between the two applications. A heavy layer of properly graded aggregate is desirable; it can interlock so that it does not depend entirely upon adhesion to stay in place. Its temperature should not be less than 40°F during application, and in cold weather the need for heating it immediately before use should be considered. Emphasis should be given to embedment details at roof edges and corners where wind effects are usually most severe.

Conclusion

It should be noted that there are some disadvantages to the use of mineral aggregate surfacing. Apart from the added dead weight. which must be carried by the deck and structure, the principal difficulty relates to inspection and maintenance. The aggregate surfacing hides defects and breaks in the membrane and, of course, must be removed to make repairs. For most bituminous roofs a surfacing is essential if reasonable service is to be expected, and mineral aggregate, properly specified and applied, is economical and effective. A thin layer of small size aggregate will not give as good protection as a heavy layer of graded material, although the coverage may appear to be the same. By protecting the bitumens from the ultraviolet rays of the sun, abrasion from wind and rain, and casual light foot traffic, such surfacing can substantially extend the life of bituminous roofs.