FACTORS INFLUENCING ANCHOR PROFILE

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Abstract: Anchor profile achieved during field blast cleaning operations is often found to be deeper than expected, even when available information suggests the size of the abrasive selected was appropriate. Three parameters long identified as influencing anchor profile depth were evaluated under laboratory conditions. This paper discusses the results obtained by changing blast nozzle pressure, angle of attack (incidence) and stand-off distance on the anchor profile achieved when blast cleaning with steel grit. Anchor profiles obtained from preliminary field data are also briefly described.

INTRODUCTION

Substrate cleanliness prior to the application of industrial coatings is recognized as being very important to achieve long term coating performance. Substrate roughness (texture) is also known to be important for performance since bonding (adhesion) of the prime coat is improved, but the texture can not be so deep as to prevent the prime coat from achieving complete coverage. When abrasive blast cleaning is the method of surface preparation, the degree of cleaning and roughness are typically specified. The degree of cleanliness is normally one of SSPC/NACE Joint Surface Preparation Standards, e.g. SSPC- SP 10/NACE No 2 "Near White Blast Cleaning." The roughness (know as anchor profile or surface profile), is specified separately as it is unique to the coating system (i.e., specific ranges are not included in the requirements of the blast cleaning standards). The required anchor profile range may be established by the specifier, or simply designated "…as per the coating manufacturer." In either case, selection of the proper type and size abrasive is necessary in order to provide the desired roughness. Guidance is available in the literature and market place, but is it accurate for all situations?

BACKGROUND

A steel bridge project required abrasive blast cleaning removal of the existing paint according to SSPC-SP 10/NACE No 2, Near White Blast Cleaning. In addition, an anchor profile of 1.5 to 3.0 mils was to be achieved using a recyclable abrasive. The abrasive selected for use was a blend of G40 and G50 steel grit. The initial anchor profiles generated by abrasive blast cleaning of the existing steel were around 2.7 mils but increased to an average of 4.2 mils after three weeks and 4.7 mils by the end of three months. The median[1] profile depth was 4.8

[1] The median is the midpoint of all values reported meaning half of the values (50%) were greater (or equal to) and 50% of the values were less than (or equal to) 4.8 mils.

mils[2]. Where did the high anchor profile come from? What must be done to obtain the desired anchor profile? Did the pre-existing anchor profile contribute to the generation of the high anchor profiles?

Several parameters have historically been identified as influencing the depth of anchor profile including the size, hardness, and shape of the abrasive. Therefore, one of the first steps to achieving the desired anchor profile is the proper selection of the abrasive. The known information was that the steel substrate was previously painted and had areas of corrosion, a recyclable abrasive was required for blast cleaning at least some portions of the structure, and steel shot could not be used. Steel grit was a logical abrasive choice. Once the abrasive type is selected, the abrasive size must be selected to provide the required anchor profile depth. Although the size of abrasive is the principal factor in determining profile depth, it should also be selected with consideration of the blast cleaning operating parameters controlled on site; blast nozzle pressure, distance to the work piece and angle of attack as these operating parameters can have some influence over the anchor profile achieved.

Guidance in SSPC literature indicated that the typical anchor profile achieved with G40 steel grit should be 2 to 2.5 mils and for G50 steel grit it should be 1.5 mils. It was noted that these values were typical with blast nozzle pressures of 90 to 100 psi (1). Similar typical anchor profile depths for G40 and G50 steel grit were also present in literature from an abrasive manufacturer (2) and a blast cleaning equipment/ abrasives supplier (3). In contrast, anecdotal information from coating inspectors indicated that, in their experience, use of G40/G50 steel grit in the field generally produced anchor profiles in excess of 3 mils. Further, Beitelman (4) reported selecting a G50 size steel grit abrasive specifically to generate a surface profile of 3 to 4 mils. He reported average anchor profile depths ranging from 4.1 to 4.4 mils. Abrasive blast cleaning was performed at a nozzle pressure of 95 to 100 psi at a stand-off distance of 18 inches from the steel substrate.[3]

The contradiction in information regarding the expected profile suggested that the profile actually generated by the abrasive or abrasive blend used should be evaluated. In addition, the operating parameters, under control of the operators, should be varied in a controlled manner to determine how they may affect the profile generated. The initial phase of the investigation was undertaken by conducting a laboratory test panel study.

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[2] Replica tape was used to measure and document the anchor profile depth. The method is described in Method C of ASTM D 4417, Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel, and NACE RP0287, Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using Replica Tape.

[3] Beitelman's work was conducted to investigate the effect recycling on the angularity of steel grit abrasive and what affect that may have on adhesion of metallizing and epoxy zinc rich coatings.

TEST PANEL STUDY

Design

A test panel study was undertaken to determine what anchor profile would be generated by abrasive blast cleaning with commercially available G40/G50 blend steel grit abrasive. The abrasive for the study was a blend of G40/G50 steel grit obtained from the same source used by the project contractor. Three hundred pounds of abrasive were delivered directly from the abrasive supplier to the physical testing facility. In addition, grab samples of unused and recycled G40/G50 steel grit abrasive were obtained from the project site. The grab samples and supplied abrasive were subject to sieve analysis for comparative purposes. The size distribution analysis was performed in accordance with ASTM C 136, Test Method for Sieve Analysis of Fine Sand and Coarse Aggregates.

The supplied G40/G50 abrasive was used to blast clean six A36[4] hot rolled carbon steel test panels, each 12" x 12" x 1/4" in size. The initial condition of the panels was Rust Grade A, intact mill scale, little or no rust visible. Blast nozzle pressure, stand off distance, and blast angle were varied to aid in assessing the impact of these operating parameters on the anchor profile. The six test panels used were divided into four 6" x 6" quadrants (A, B, C, and D). Each quadrant was abrasive blast cleaned, using the operating parameters below, with adjacent quadrants shielded.

Table 1- Blast Cleaning Parameters by Panel Quadrant

Panel Quadrant	Stand-off Distance	Nozzle Pressure	Panel Quadrant	Stand-off Distance	Nozzle Pressure
A	18"	103 psi	B	18"	118 psi
C	12"	103 psi	D	12"	118 psi

The different values used for the operating parameters were selected to reflect typical project operations as well as guidance provided for abrasive blast cleaning. The blast angle was established for each panel, ranging from 60^o to 90^o. The changed operating conditions were conducted in duplicate by having panel pairs. Panels 1 and 2 were blast cleaned at an angle of 80^o to 90^o, panels 3 and 4 were blast cleaned at and angle of 60^o and panels 5 and 6 were blast cleaned twice, first at an angle of 80^o to 90^o then at an angle of 60^o. The abrasive size (distribution) was the only variable that was not altered.

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[4] ASTM A36, Standard Specification For Carbon Structural Steel. ASTM International. West Conshohocken, PA.

Results

The results of the abrasive sample sieve analyses are shown in Table 2. The cumulative distribution of retained abrasive is also provided graphically in Figure 1.

Table 2 - Sieve Analysis of Steel Grit Abrasive
Percent Retained by Sieve Mesh Size[a]

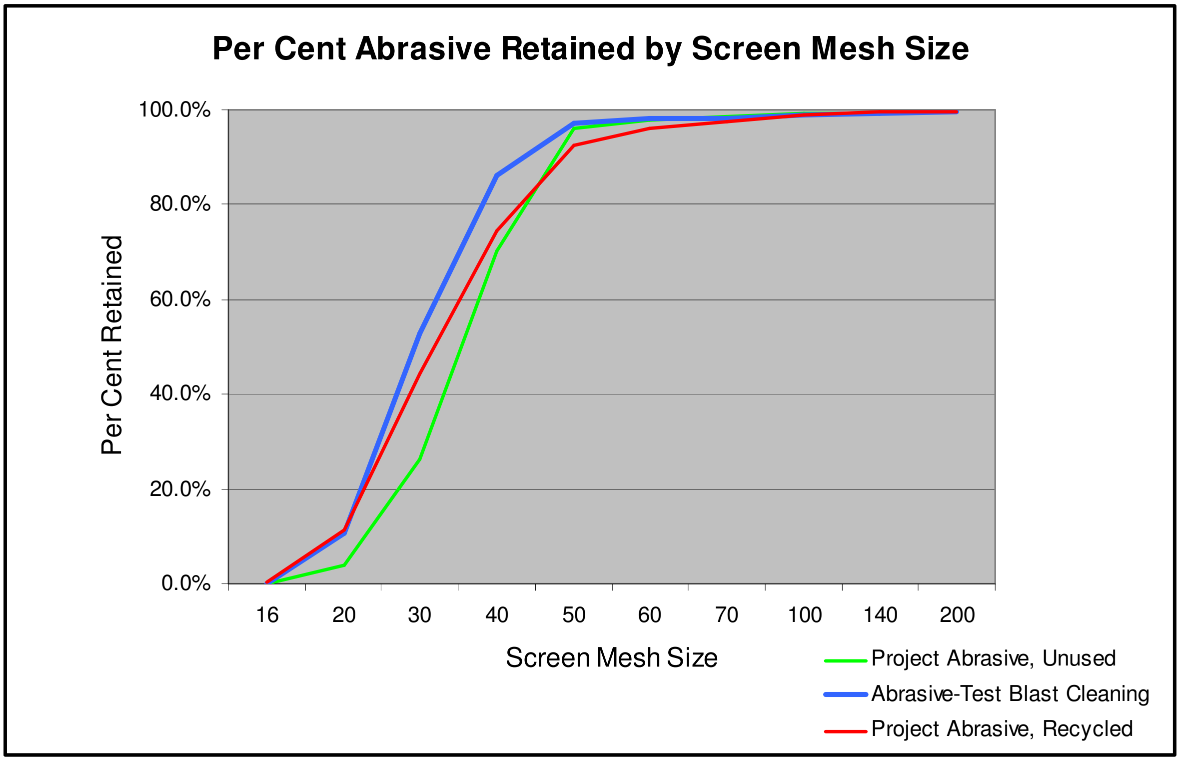
Sieve Mesh	Project, Unused	Unused, Cumulative	Supplied For Test	Supplied, Cumulative	Project, Recycled	Recycled, Cumulative
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.5%	0.5%
20	4.1%	4.1%	10.6%	10.6%	10.7%	11.2%
30	22.1%	26.2%	42.2%	52.8%	33.1%	44.3%
40	44.0%	70.2%	33.4%	86.1%	30.1%	74.4%
50	26.0%	96.1%	11.1%	97.2%	18.3%	92.7%
60	1.8%	97.9%	0.9%	98.1%	3.3%	96.0%
70	0.7%	98.6%	0.3%	98.4%	1.5%	97.5%
100	0.6%	99.2%	0.6%	99.0%	1.6%	99.0%
140	0.2%	99.4%	0.4%	99.4%	0.5%	99.5%
200	0.3%	99.7%	0.2%	99.6%	0.3%	99.8%
270	0.1%	99.8%	0.1%	99.7%	0.1%	99.9%
Pan	0.2%	100.0%	0.3%	100.0%	0.1%	100.0%

a-The sieve mesh size is based on the number of screen strands per linear inch. The higher the mesh number (strands), the smaller the opening size and size of particle that will pass through. The cumulative values provide the proportion of abrasive, by weight larger than the stated sieve mesh.

The abrasive provided directly from the supplier had an average particle size of 0.52 mm (0.020 inch) compared to 0.49 mm (0.019 inch) for recycled abrasive and 0.44 mm (0.017 inch) for new abrasive in the field. It was thus indicated that the abrasive supplied for blast cleaning test panels had a somewhat larger size distribution than both of the unused and recycled abrasive grab samples from the project. The data also indicate the recycled field abrasive has a slightly larger size distribution than the unused field abrasive. This might be attributed to the abrasive recycling unit stripping off portions of the smaller fractions but the data does not show evidence of a truncation of fine particle sizes. Generally, new abrasive is added to the stock of recycled abrasive to maintain a “working mix”.

The differences may simply reflect lot to lot variation in the size distribution. SSPC-AB 3, Ferrous Metal Abrasives, Table 2, Metallic Grit Size Specifications shows that a maximum of 70% of the abrasive (by weight) of G40 steel grit should be retained on a 40 mesh (0.0165 inch screen opening) screen and minimum of 80% retained on a 50 mesh (0.0117 inch) screen. It also shows that a maximum of 65% G50 steel grit should be retained on a 50 mesh screen and minimum of 85% on an 80 mesh screen. Since variation in size distribution of the parent G40 and G50 materials is permitted (within the stated limits). It is reasonable to expect lot to lot size distribution variation of the blended abrasive.

Figure 1- Cumulative Percent of Abrasive Retained by Screen Mesh Size



The anchor profile depths generated by abrasive blast cleaning with the supplied G40/G50 steel grit were measured in triplicate using Testex™ X-Course Plus replica tape[5]. The overall average anchor profile was 5.0 mils with a range of 4.4 to 5.6 mils.

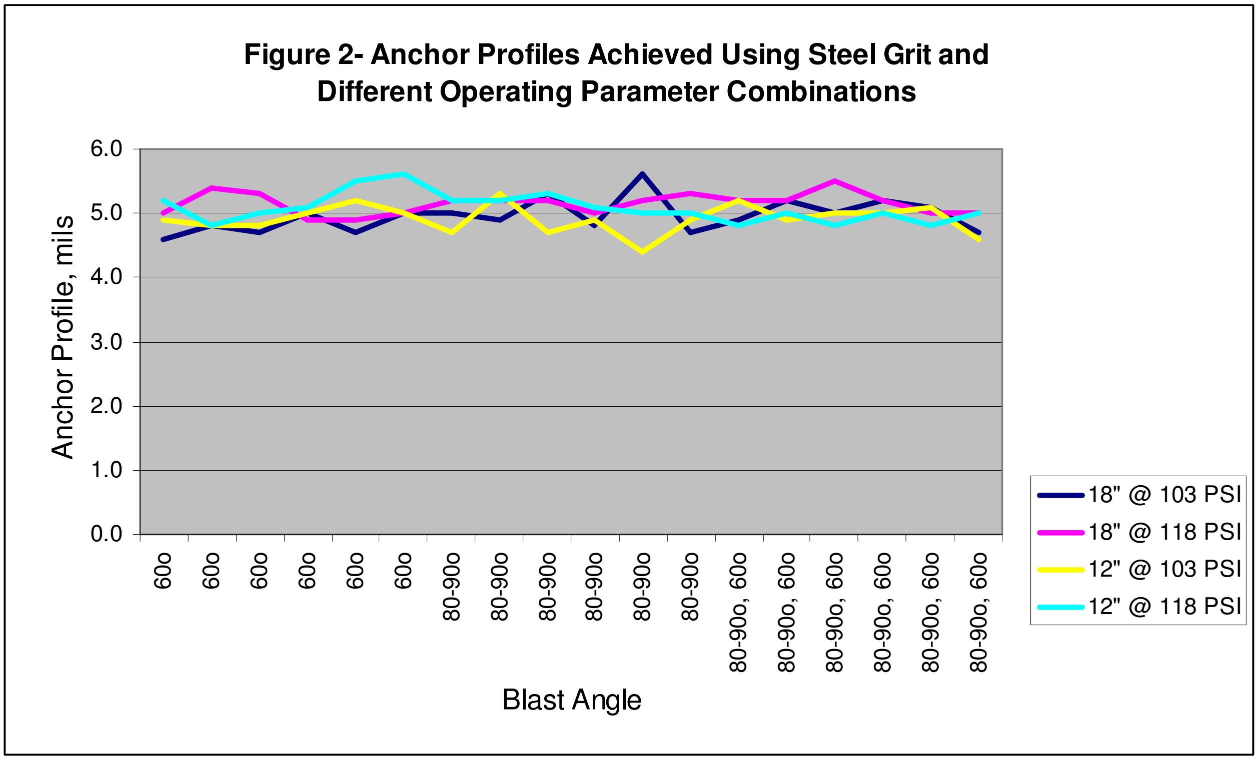
The information has been summarized in the following Table 3 which shows the average anchor profile generated under the indicated operating parameters.

Table 3- Average Profile Depth by Panel Quadrant
for Various Operating Parameters

Panel Quadrant	Standoff Distance	Nozzle Pressure, psi	Blast Angle 80-90°	Blast Angle 60°	Blast Angle 80-90° Then 60°
			Avg. Profile	Avg. Profile	Avg. Profile
A	18"	103	5.1 mils	4.8 mils	5.0 mils
B	18"	118	5.2 mils	5.1 mils	5.2 mils
C	12"	103	4.8 mils	5.0 mils	5.0 mils
D	12"	118	5.1 mils	5.2 mils	5.0 mils

[5] ASTM D4417, Method C.

Comparisons using paired data can estimate the influence of the operating parameters on anchor profile. In Figure 2 below such a comparison is made. The color lines represent the different combinations of standoff distance and nozzle pressure. The bottom scale (X axis) shows the profile replicates categorized by blast cleaning angle.



It is evident from the data that the anchor profile, regardless of the combination of operating parameter values employed, is approximately 5 mils. Some variation is apparent and much of it may be related to the variability inherent in the measurement method. The differences in anchor profile for matched data pairs were not found to be statistically different. For example, the difference between each anchor profile obtained at 103 psi and the anchor profile obtained at 118 psi for pairs with the same standoff distance and blast cleaning angle was 0.2 mils. However, the standard deviation of the difference was 0.29. Caution should be exercised when attempting to identify trends or the significance of one operating parameter compared to another. Blast cleaning at 80 ^{O} - 90^{O} and then at 60^{o} does appear to reduce the variability (range) of the anchor profile compared to blast cleaning at one of the angles only-yet the average profile depth isn't changed. Table 4 provides all of the anchor profile readings obtained by operating parameter.

Table 4 Anchor Profile Depth Generated on Test Panels Blast Cleaned with G40/G50 Steel Grit Abrasive under Differing Operating Parameters

Panel No.	Quadrant	Stand-off	Pressure, psi	Blast Angle 1	Blast Angle 2	Reading 1	Reading 2	Reading 3	Average
250347-1	A	18"	103	80-90°	NA	5.0	5.3	5.6	5.3
	B	18"	118	80-90°	NA	5.2	5.2	5.2	5.2
	C	12"	103	80-90°	NA	4.7	4.7	4.4	4.6
	D	12"	118	80-90°	NA	5.2	5.3	5.0	5.2
250347-2	A	18"	103	80-90°	NA	4.9	4.8	4.7	4.8
	B	18"	118	80-90°	NA	5.2	5.0	5.3	5.2
	C	12"	103	80-90°	NA	5.3	4.9	4.9	5.0
	D	12"	118	80-90°	NA	5.2	5.1	5.0	5.1
250347-3	A	18"	103	60°	NA	4.6	4.7	4.7	4.7
	B	18"	118	60°	NA	5.0	5.3	4.9	5.1
	C	12"	103	60°	NA	4.9	4.8	5.2	5.0
	D	12"	118	60°	NA	5.2	5.0	5.5	5.2
250347-4	A	18"	103	60°	NA	4.8	5.0	5.0	4.9
	B	18"	118	60°	NA	5.4	4.9	5.0	5.1
	C	12"	103	60°	NA	4.8	5.0	5.0	4.9
	D	12"	118	60°	NA	4.8	5.1	5.6	5.2
250347-5	A	18"	103	80-90°	60°	4.9	5.0	5.1	5.0
	B	18"	118	80-90°	60°	5.2	5.5	5.0	5.2
	C	12"	103	80-90°	60°	5.2	5.0	5.1	5.1
	D	12"	118	80-90°	60°	4.8	5.1	4.7	4.9
250347-6	A	18"	103	80-90°	60°	5.2	5.2	4.7	5.0
	B	18"	118	80-90°	60°	5.2	5.2	5.0	5.1
	C	12"	103	80-90°	60°	4.9	5.0	4.6	4.8
	D	12"	118	80-90°	60°	5.0	5.3	5.0	5.1

PRELIMINARY FIELD TEST DATA

Design

A preliminary review of data obtained from field blast cleaning of six test panels, completed in October 2006, was not fully evaluated a the time this paper was prepared. The test panels used were 12” x 12” x 1/4” with intact mill scale (Rust Grade A). The panels were held on the surface of bridge elements with magnets and blast cleaned at the same time as adjacent bridge elements. The panels and bridge elements were abrasively blast cleaned to SSPC-SP 10/NACE No. 2 with recycled G40/G50 steel grit at the same time by the same operator. A blast nozzle pressure of 100 psi was measured. The blaster was asked to produce the specified degree of cleanliness but was not directed as to the blast angle, standoff distance or dwell time to use.

Results

The average anchor profile for six test panels was 4.0 mils and the range was 3.1 to 4.5 mils. Testex™ X-Course replica tape was used for measuring the anchor profile. The steel substrate next to the test panels included surfaces having an intact coating system and surfaces having Rust Grade D, completely covered with rust, pitting visible. The existing profile on the bridge steel was measured on surfaces where the intact coating was stripped[6] from the surface. The profile of the steel beneath the existing coating system ranged from 3.3 to 4.1 mils (average 3.7 mils). Portions of the existing steel with coatings intact were then blast cleaned. The resulting anchor profile averaged 4.0 mils and ranged from 3.5 to 4.3 mils, which was consistent with the profile achieved on the new mill scale-bearing panels that were blast cleaned at the same time. A more detailed discussion of the field study findings will be available after a thorough evaluation of the data.

CONCLUSIONS

- Abrasive size is the primary determinant of the anchor profile achieved confirming numerous observations and findings by others.
- Changing operating parameters, over the range studied, does not significantly alter the anchor profile achieved when the abrasive size (distribution) remains the same.
- Abrasive blast cleaning with G40/G50 steel grit produced an anchor profile deeper than specified.
- The difference between the anchor profile obtained in the laboratory and that obtained in the field probably is related to the differences in abrasive size between the supplied abrasive and recycled abrasive used on the project.
- Although not tested, it is likely that the size of the abrasive will have to be changed in order to consistently achieve an anchor profile of less than 4 mils.

RECOMMENDATIONS

- Additional studies by SSPC, abrasive manufacturers or other testing organizations on the anchor profiles attributed to different abrasive types and sizes using operating parameters common to field production blast cleaning.
- Continued and increased use of abrasive blast cleaned field test sections prepared prior to production operations. This will serve to determine if the selected abrasive will achieve specified anchor profiles under field conditions.

[6] Chemical stripping followed by blast cleaning with walnut shell abrasive was used to expose the existing profile.

References

(1) Surface Preparation Specifications- Surface Preparation Commentary for Steel and Concrete Substrates (SSPC-SP Com). Systems and Specifications. SSPC Painting Manual Volume 2, Ninth Edition. SSPC- The Society for Protective Coatings. Pittsburgh, PA.

(2) METgrit Abrasive Specification Sheet (Annotated). Chesapeake Specialty Products, Baltimore, MD

(3) Clemtex Anchor Profile Pattern Standards. Clemtex, Houston, TX

(4) Al Beitelman, "Recycling Steel Grit", Journal of Protective Coatings and Linings (July 2003) pg 58.