LAFARGE TARMAC

Investigation Report

Aggregate Supplies to Whitwell Quarry Concrete Plant

'Pop-Outs' External Slab & M1 Extruded Barrier

Prepared by

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LAFARGE TARMAC

Executive Summary

Whitwell Quarry was contacted on the 29th May 2014 by our Internal RMX department regarding two Customer complaints resulting from Concrete supplied a few months previously.

The first, [redacted] was supplied on the 18th February 2014, the second, for extruded barrier works to Costain on the M1 Motorway was supplied 22nd February 2014 both of which were found to exhibit signs of surface damage manifesting as 'pop-outs'.

XRF analysis of material taken from the surface 'pop-outs' confirmed the material to be calcined dolomite, that is 'burnt' or 'partially burnt' dolomite. When exposed to water 'calcined dolomite' is subject to an expansive reaction which causes characteristic surface blemishes as manifested in the Sites supplied by Whitwell Concrete plant.

A root cause analysis was undertaken, to determine the causative agent, focussing on the 4/20mm Whitwell limestone as this was the only source of aggregate supplied to Whitwell Concrete Plant.

The investigation identified that the primary crusher at Whitwell Quarry had been out of action for two weeks in early February 2014 due to a motor failure. During this period the site was low on single sized products, therefore 4/20mm aggregate was taken from the fixed plant and combined with other mineral at the wash plant to produce concrete aggregates supplied to RMX and other Customers.

Our investigation concluded that 'calcined dolomite' was introduced into the concrete aggregate manufacturing process in the form of small quantities of aggregate reclaimed from an excess material storage bay over a period of 4 weeks between the 13th February until 18th March 2014. This material was then blended with fresh face material to produce concrete aggregates resulting in the inclusion of small amounts (less than 0.9%) of 'calcined dolomite'. The vast majority of the aggregate produced and sold was found to be consistent with those declared in Appendix 1 by Lafarge Tarmac for use in concrete mixes.

Information from Lafarge Tarmac RMX indicates that due to the [redacted] however the concrete barrier shows little evidence of deterioration beyond the pop-outs and the incidence of these surface blemishes appears to be both limited and finite.

Once the pop-out associated with a particular calcined dolomite particle has occurred, there will be little scope for further deterioration in that vicinity, it should therefore be possible to carry out localised repairs.

Finally the report outlines how Whitwell Quarry has amended their manufacturing and quality control systems to ensure the continued supply of quality aggregates to RMX.

1. Introduction

Washed 4/20mm Dolomitic limestone aggregate is supplied to Whitwell Concrete plant for the manufacture of concrete products, for use in civil engineering applications.

A subsequent investigation has been undertaken at Whitwell Quarry to understand the root cause of the problem, based upon the previously identified time frame, including analysis of the material to determine its composition, origin and how it was introduced into the manufacturing process.

Finally the report outlines how Lafarge Tarmac has amended their manufacturing and quality control systems to ensure the continued supply of quality aggregates to RMX.

2. Site Observations

The surface 'pop outs' varied in size and shape, but were typically 10 - 100mm in diameter as displayed in photographs (Fig 1).

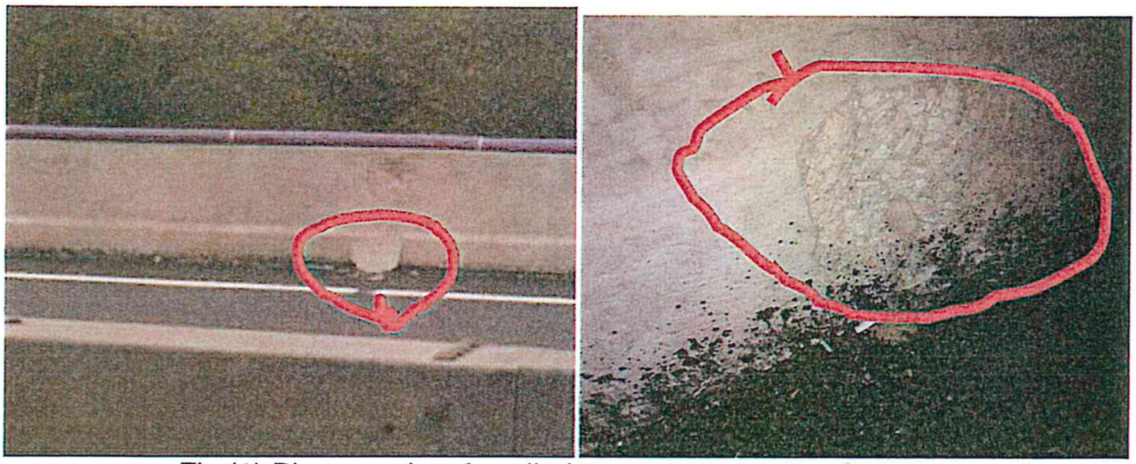

Fig (1) Photographs of spalled concrete area or surface 'pop-outs'

Typically an aggregate particle could be observed at or near the base of the surface pit, which had apparently induced the pop-out. The aggregate particle remained wholly embedded in the concrete, sometimes being fractured, with some of the particle having detached from the surface. These particles which ranged in size from 3 to 10mm in diameter were typically white coloured, granular and relatively soft and friable. Importantly, there was no evidence of secondary deposits or staining of the surrounding concrete matrix adjacent to the 'pop-out' formation.

Characteristically the 'pop-outs' were reminiscent of those caused by frost–susceptible micro-porous aggregate particles within concrete surfaces exposed to freezing conditions. However, this seemed an improbable explanation for concrete cast products manufactured during and exposed to mild conditions experienced from March to June 2014. It was therefore concluded during our site visit that the origin and composition of the particles apparently inducing the 'pop-outs' would need to be established in order to reach a reliable conclusion of the cause of the issue.

The initial conclusion was thought to be a weak aggregate with high water absorption which had caused the failure. Further investigation was made by Lafarge Tarmac, samples being sent for independent testing.

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3. Technical Analysis of Samples

Analysis of the samples taken from the site, were carried out at the TATA Research Laboratory on Teesside.

Test results identified the following points:

1 Full loss on ignition for Whitwell Dolomite is typically 47% - The Loss on ignition value of the sample at 15.4% indicates that the material is partially calcined or has been fully calcined and subsequently 'diluted' with virgin aggregate

2 The MgO value found at 28.5% also indicates that the material is partially calcined - Typical MgO for Whitwell Dolomite is 18%

4. Stone Processing Circuit (Source of deleterious calcined dolomite)

Blasted face stone is transported to the processing plant via dump trucks. A Primary jaw crusher reduces the stone in size down to around 250mm before discharge onto the primary stockpile. From here the stone is then fed directly into a secondary crusher further reducing in size before a conveyor belt takes the stone to the tertiary crusher house where it is temporarily held in a bunker. At the bottom of the bunker are three feeders each giving a different option for the next stage of processing as follows:-

1. Crushing in an impact crusher.
2. Crushing in a cone crusher.
3. By passing both crushers directly to the sizing screens.

Following this stage, aggregate is transferred via a chute onto a conveyor belt to two vibrating screens for sizing and then storage in bunkers, with any excess being taken by conveyor belt to a bay within the stocking area. Our investigation has identified that it is at this point that a small percentage of 'calcined dolomite' exiting the kiln process has been spilling onto the discharge conveyor and contaminating the subsequent aggregate.

5. Quantifying Calcined Dolomite Present

Due to the fixed plant breaking down, 4/20mm material within the excess stock bay was processed through the washing plant over a 4 week period between 13th February and the 14th March. From our production records it is estimated that approximately 2,800 tonnes of 4/20mm material was reprocessed in this manner. Testing conducted on Monday 23rd June 2014 identified that material within the excess storage bay, produced under similar conditions to those of the period in question, contained around 4.46% calcined dolomite. (For calculation details, see Appendix 1).

During the production period in question 14,447t of concrete aggregates were produced, which based upon the above investigation, contained less than 0.9% of calcined dolomite.

Practically, the washing process will have further broken down the softer calcined dolomite, via hydration, which would ultimately have ended up in the tailings lagoon, so reducing the actual percentage of contaminant in the finished product probably below the level stated above.

6. Impact of Calcined Dolomite upon final Products

Information from Concrete Slab Surface Defects paper via Portland Cement Assessment dated 2001: - Title Pop-outs; page 9 - first paragraph indicates pop-out (slightly different to spalling (Appendix 2)).

Under reasons section 9, two reasons given (excluding freeze/thaw).
1 Porous Rock- Moisture/absorption can give a pop-out
2 Hard burnt Dolomite, pyrite, coal, shale, soft grained limestone or chert

Table within Soundness of Aggregates for Concrete Reference Book Neville Properties of Concrete; gives a table of "Permissible Quantities of Unsound Particles prescribed by ASTM C 33 - 78 (American BS).

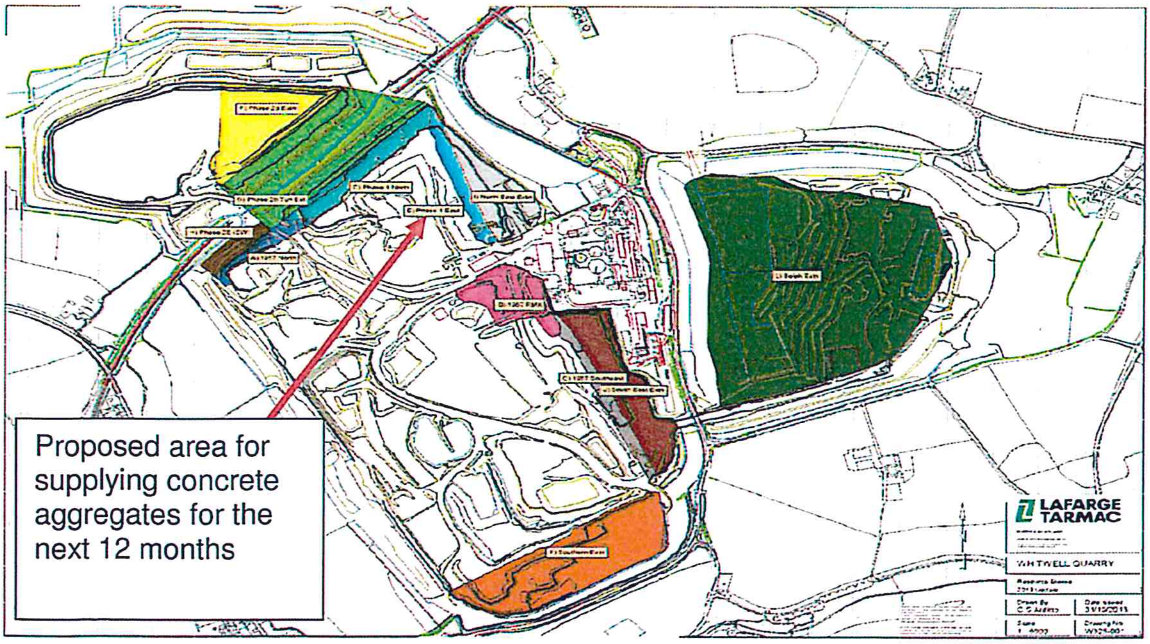
TYPE OF PARTICLE	MAX IN FINE AGGREGATE	MAX IN COARSE AGGREGATE BY WEIGHT
Friable Particles	3%	3 – 10%*
Soft Particles	-	3 – 10%
Coal	0 -1%	0 – 1%
Chert that will disintegrate	-	3 – 8%
* Including chert		
* Appearance		
* Depending on exposure		

Page 154 - Indicates unsound aggregates or low densities over 2 to 5% can affect strengths; and leads to the above table (Reference: - AM Neville Properties of Concrete 3rd Edition).

It is therefore concluded that because the aggregate contains less than 0.9% of unsound particles, the aggregate still meets the requirements for concrete aggregates and further, that there should be no impact upon the overall strength of the finished products, other than cosmetic appearance

7. Future Production

Fig (2) Remaining Reserve Blocks



The remaining reserve is well understood due to exploration drilling, which together with our historical experience of the deposit means we are confident that we have sufficient reserve of Civil Engineering grade to sustain manufacture of quality concrete aggregates.

Production systems have now been amended to eliminate calcined dolomite from entering the concrete aggregates manufacturing process as follows:

- Using mobile crushing and screening plant at the face to produce civil engineering aggregates
- The stockpiles have been strategically situated in a designated area to prevent cross contamination from other stockpiles.
- To ensure continuous product supplies, Whitwell Quarry is increasing its production rates on single sizes, particularly 4/20mm, to ensure supply in cases of plant breakdown.
- Production of 4/20mm varies throughout the year, with between 100,000 to 140,000 tonnes per annum for use in civil engineering.

8. Recommendations

A joint inspection regime i.e. weekly to be established between Whitwell Quarry Technical and RMX Technical for concrete aggregates manufactured at Whitwell to ensure ongoing integrity of material supplied for concrete products.

Monthly meetings between RMX and Whitwell quarry management.

Whitwell Quarry to increase stock levels of 4/20 mm product for RMX.

Additional process control measures mentioned previously and operator awareness training, have been introduced that will prevent any future repeat of calcined dolomite entering the production process and subsequently contaminating our saleable products.

9. Conclusions

Deleterious material in the form of calcined dolomite entered the concrete aggregate manufacturing process as a result of a breakdown of the main processing plant between the 13th February and the 14th March.

Where they occurred, the pop-outs were limited to 100mm diameter and were typically just a few millimetres deep, associated with a single particle of calcined dolomite.

There is no evidence of any deterioration of the concrete barrier matrix beyond the pop-outs and the incidence of these surface blemishes appears to be limited and finite. Localised repair of pop-outs would seem to be the most practicable remediation solution.

The total amount of calcined dolomite in the aggregate supplied represented less than 0.9% of the total supplied to Customers so limiting the extent of subsequent effects.

The fact that there was a substantial number of pop-outs evident in the [redacted] and a greatly reduced number in the M1 barrier supplied 20th February indicates that this was an isolated contamination issue that does not present a subsequent risk to supplies after this date. Lafarge Tarmac concludes that the impact upon the concrete will represent a cosmetic/surface issue and will not adversely affect structural integrity.

Appendix 1: Calculation of % of Calcined Dolomite Contamination

Whitwell 4/20mm sold to Customers from 12th February to 14th March, the total sales are 14,447.47 tonnes of which it is estimated that around 2,800 tonnes was blended from the primary excess storage bay. This estimate is upon known production rates and shift patterns.

Testing conducted on Monday 23rd June 2014 identified that material within the excess storage bay, produced under similar conditions to those of the period in question, contained around 4.46% calcined dolomite.

The total tonnage of calcined dolomite mixed with virgin aggregates is estimated at around 128 tonnes, or in overall terms less than 1% of the concrete aggregate produced during this period.

Table 1 – Whitwell Quarry Customer Sales Feb – March 2014

Material 12th February to 14th March 2014	Order QTY
ULTIFLOW 2/6MM LAYING COURSE	19.86
ULTIFLOW 4/20MM PERMEABLE SUB-BASE	79.78
0/6MM ALL-IN SELECTED LIMESTONE	20.18
0/10MM ALL-IN AGGREGATE LIMESTONE	39.54
4/10MM SINGLE SIZE LIMESTONE	2,480.74
4/20MM GRADED LIMESTONE	19.76
4/20MM GRADED CONCRETE AGG LIMESTONE	11,454.69
10/20MM SINGLE SIZE AGGREGATE LIMESTONE	275.44
WHITWELL DERBYSHIRE CREAM 10/20MM AGG	27.90
0/10MM GOLDEN AMBER GRAVEL	29.58
	14,447.47

Calculation Method

Two samples taken from the primary scalping stockpile identified the following;

Sample 1 – taken at 08:15am total weight 306.6 grams, with 19 grams calcined lime.

Sample 2 – taken 12:00 noon total weight 326 grams, with 9.2 grams calcined lime.

Total = 632.6 grams - 28.2 grams calcined = 4.46% average

14447.47 total sales from the 12th February to 14th March.

2800 with 4.46% calcined lime = 127.68 tonnes

127.68/14447.47 = 0.88% maximum potential contaminated with calcined lime

This equates to a potential less free contaminated of 99.12%.