EXPLANATORY REPORT

REPORT OF PETROGRAPHIC EXAMINATION

Date: June 9, 2006

CTLGroup Project No.: [redacted]

Re: Petrographic Examination of Concrete Core Samples, [redacted]

Two concrete core samples, designated as #3RF (Fig. 1) and #4TP (Fig. 2), were received on April 28, 2006, from Ms. [redacted], [redacted], Hobbs, New Mexico. The core samples were reportedly extracted from a concrete floor slab in Carlsbad, New Mexico, that exhibited cracking within 24 hours of placement. Core #4TP exhibits cracking, while Core #3RF does not. According to information provided by Ms. [redacted], the core samples were extracted within 1.5 ft. of each other. Petrographic examination (ASTM C 856) of the submitted samples was requested to characterize and determine a possible cause for the cracking.

FINDINGS AND CONCLUSIONS

Based on results of the petrographic examination, initial cracking of the slab appears to be the result of plastic shrinkage. Furthermore, the concrete exhibits characteristics consistent with a fairly stiff (low slump) mix.

Cracks observed on the top surface of Core #4TP have a tear-like appearance (Fig. 3) and are oriented parallel to each other. Additionally, within the upper portion of the core, crack surfaces exhibit paste-coated aggregate particles. These characteristics are consistent with plastic shrinkage cracks, which form before the concrete has set (hardened). Plastic shrinkage cracking typically occurs in hot, dry, and/or windy conditions when water evaporates from the concrete surface faster than it is replenished by the bleeding process. This rapid drying of the surface creates tensile stresses which are then relieved by tearing of the fresh paste within the concrete.

Plastic shrinkage cracks typically extend only a short distance into the concrete. Cracks observed in Core #4TP, however, extend through the full depth of the slab (Figs. 2b and 4b). It is likely that, after the plastic shrinkage cracks formed along the surface, the concrete set but continued to experience moisture loss. The plastic shrinkage cracks effectively acted as contraction joints, and propagated through the full depth of the slab as a result of the subsequent drying shrinkage.

Both of the submitted core samples exhibit characteristics which suggest that the concrete may have been fairly stiff at the time of placement. Plastic deformation tears are observed in the lower portions of both cores (Figs. 5). These tears can form if the fresh concrete is disturbed after its initial placement. In a more fluid mix, the concrete would flow back into place, effectively repairing the tears. In a stiff mix, the tears remain in place. The water-cementitious materials ratio (w/cm) of the concrete is judged to be moderately low to low, indicated by a high volume of unhydrated portland cement in the paste (Fig. 6). Without the addition of admixtures to modify workability, concrete with a low w/cm will be more stiff than concrete with a high w/cm. Furthermore, a stiff concrete mix will usually bleed less, which can exacerbate the occurrence of plastic shrinkage cracking.

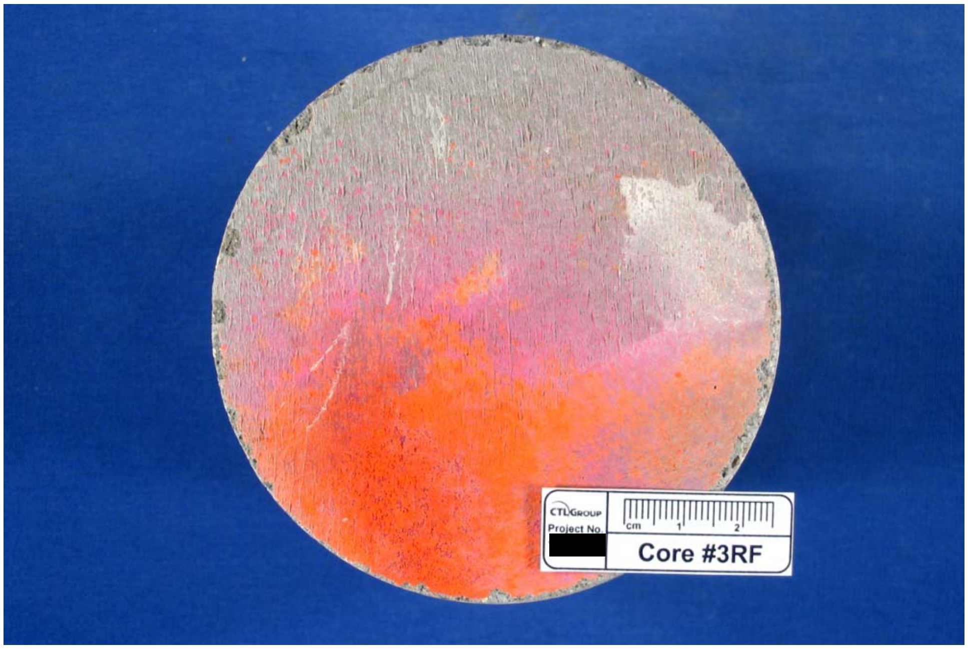
Concrete represented by each of the submitted samples exhibits very similar composition and properties. The concrete consists of calcareous and siliceous rock coarse and fine aggregate distributed in a hardened paste of portland cement and fly ash (Figs. 4 and 6). Additional findings and descriptions of the samples are provided in the attached data sheets.

METHODS OF TEST

Petrographic examination of the submitted samples was performed in accordance with ASTM C 856-04, “Standard Practice for Petrographic Examination of Hardened Concrete.” The samples were visually inspected and photographed. A slice, approximately 20-mm (¾-in.) thick, was cut longitudinally from each sample and one of the resulting surfaces of each slice was lapped. Lapped and freshly broken surfaces were examined at magnifications up to 45x using a stereomicroscope equipped with a high-intensity, variable angle, dual light source. A rectangular block, measuring approximately 25 mm (1.0 in.) wide and 38 mm (1.5 in.) deep, was cut from the near-surface region of each sample. One surface of each block was ground to a semi-polished finish. After cleaning and drying, the prepared surfaces were mounted on glass microscope slides with epoxy resin. Following epoxy hardening, the thickness of the mounted blocks was reduced to approximately 20 μm (0.0008 in.). The resulting thin sections were examined at magnifications up to 400x using a polarized-light microscope to evaluate mineralogy and microstructure.

Depth and extent of paste carbonation was initially determined by the application of a pH indicator (phenolphthalein) solution to freshly fractured and saw-cut surfaces of the concrete. The solution imparts a deep magenta stain to high-pH, non-carbonated cement paste, but does not stain reduced-pH, carbonated paste. Extent of carbonation was also confirmed during microscopical examination of the thin sections.

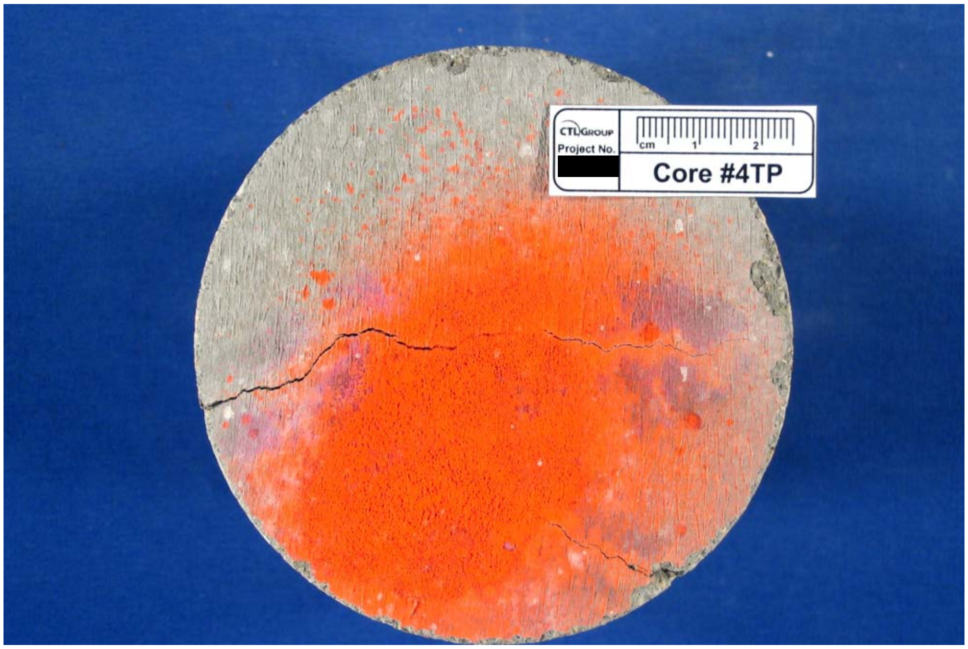
[redacted]
Microscopist
Microscopy Group



1a. Top surface.

1b. Side view, top surface at left.

Fig. 1 Core #3RF, as received for examination.



2a. Top surface.

2b. Side view, top surface at left. Note crack extends through full length of core.

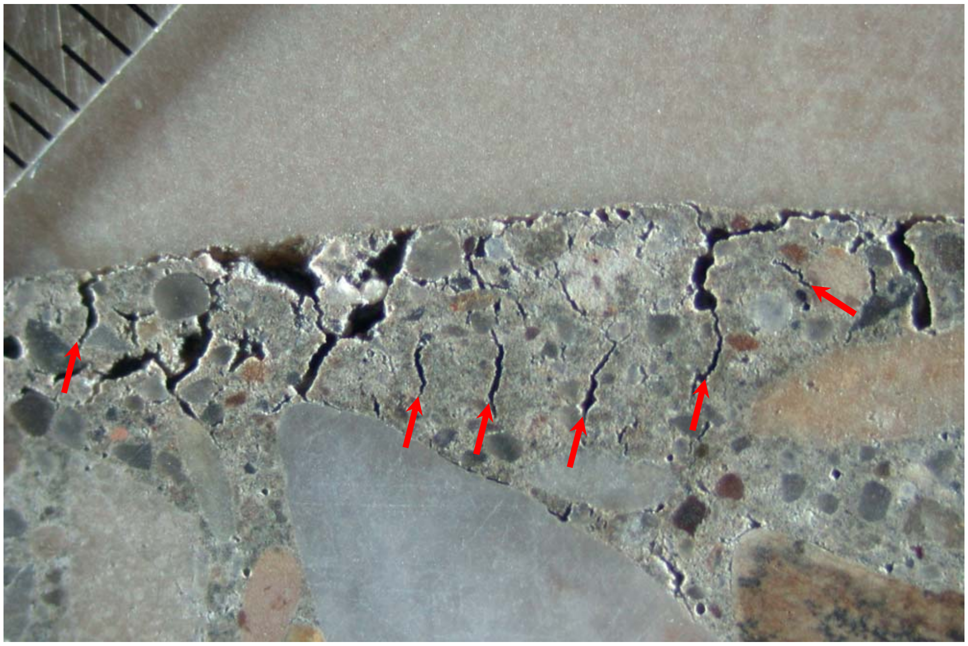
Fig. 2 Core #4TP, as received for examination.

Fig. 3 Magnified view of crack on top surface of Core #4TP. Note discontinuous, tear-like appearance of crack.

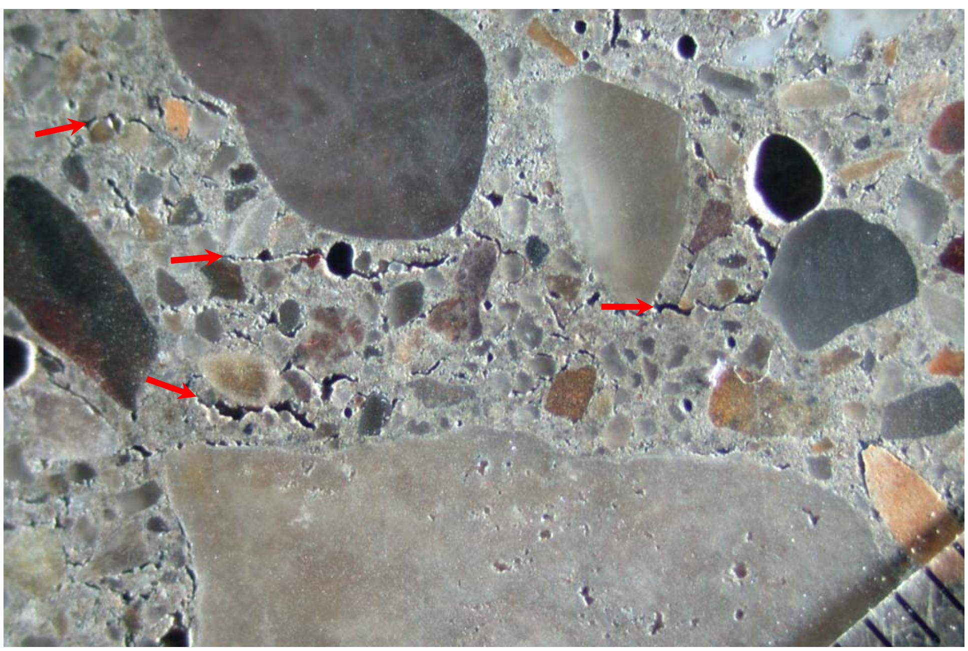
4a. Core #3RF.

4b. Core #4TP. Note crack (arrows) extends through full length of core.

Fig. 4 Lapped, longitudinal cross-sections of core samples, top surfaces at left.

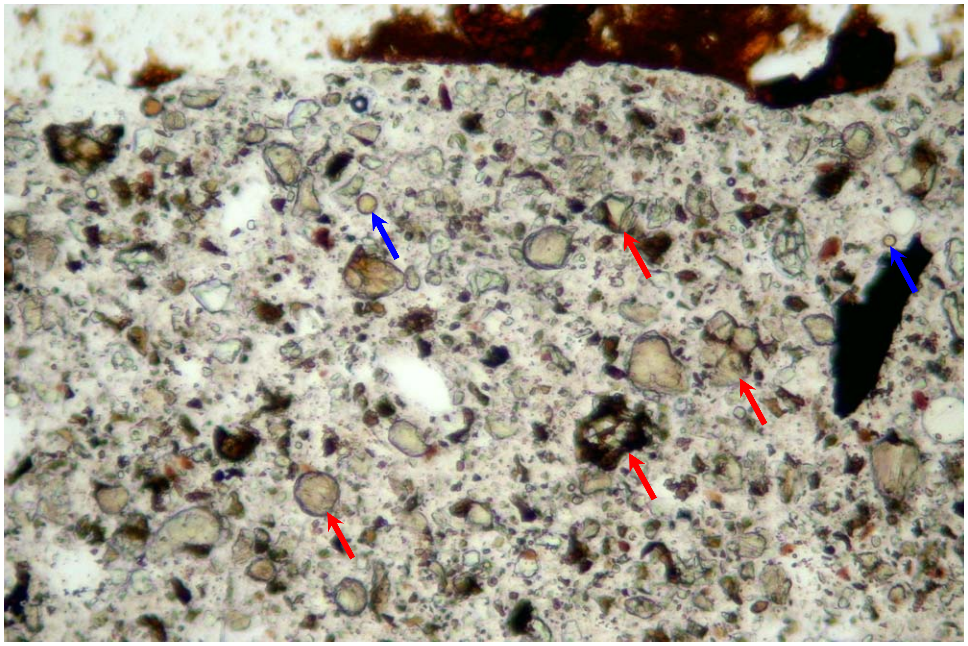


5a. Core #3RF.

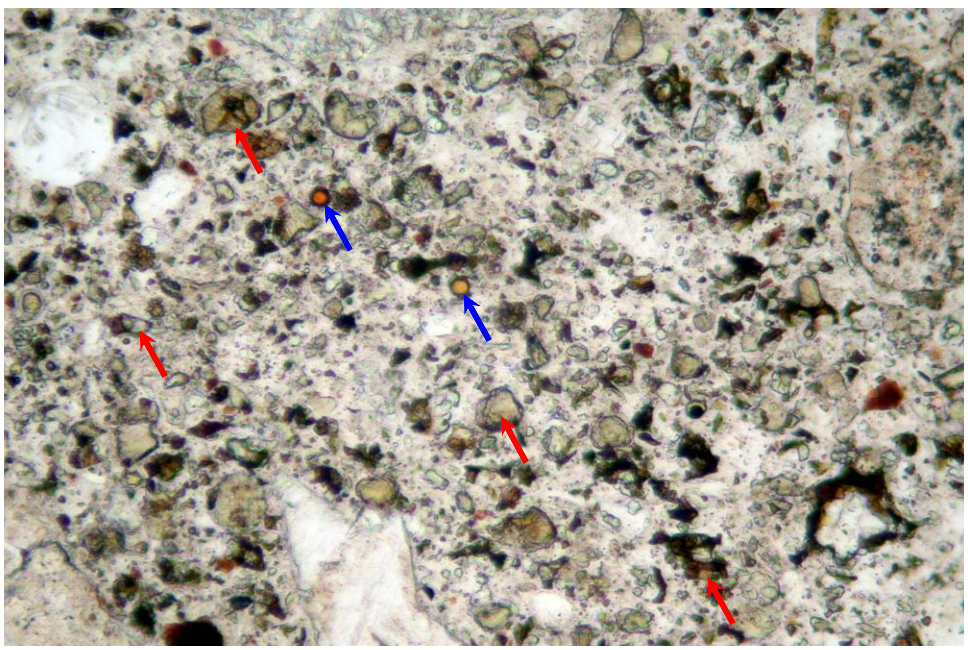


5b. Core #4TP.

Fig. 5 Magnified views of lapped longitudinal cross-sections of core samples showing discontinuous plastic deformation tears (arrows) within body of concrete.



6a. Core #3RF.



6b. Core #4TP.

Fig. 6 Thin-section photomicrographs of representative fields of cementitious paste within core samples, plane-polarized light. Red arrows indicate unhydrated portland cement clinker particles, while blue arrows designate residual fly ash spheres. Field of view approximately 0.4 mm (0.015 in.) across.

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTLGROUP PROJECT NO.: [redacted]

CLIENT: [redacted]

STRUCTURE: Concrete slab-on-grade

LOCATION: Carlsbad, New Mexico

DATE: June 9, 2006

REPORTED PROBLEM: Cracking

EXAMINED BY: [redacted]

SAMPLE

Identification: #3RF.

Dimensions: Core diameter is 95 mm (3.7 in.). Core length is approximately 165 mm (6.5 in.); full slab thickness.

Top Surface: Flat, slightly rough surface exhibits light broom finish. Surface is partially coated with orange paint but appears paste-rich, medium gray in color, and moderately soft. When wetted, surface exhibits numerous, closely-spaced craze cracks.

Bottom Surface: Smooth and slightly undulating; appears as if concrete was placed on plastic sheeting.

Cracks, Joints, Large Voids: Concrete exhibits a few fairly large entrapped air voids, measuring up to 10 mm (0.4 in.) across. No cracks or joints observed.

Reinforcement: None in core segment.

AGGREGATES

Coarse: Gravel and/or partially crushed gravel composed of limestone, chert, quartzite, igneous rocks and other rocks. A small number of particles exhibit carbonate (caliche) crusts.

Fine: Natural sand composed of limestone, quartz, chert, quartzite, igneous rocks, sandstone, and other rocks and minerals.

Gradation & Top Size: Evenly graded to an observed top size of 20 mm (0.8 in.).

Shape & Distribution: Coarse– angular to sub-rounded, and mostly equant with smooth to irregular surfaces; distribution is uniform. Fine– angular to rounded, and mostly equant with smooth to irregular surfaces; distribution is uniform.

PASTE

Color: Generally medium beige-gray. Darker beige-gray in upper 1 to 2 mm (0.04 to 0.08 in.).

Hardness: Somewhat variable, ranging from moderately soft to moderately hard. Moderately soft in upper 2 mm (0.08 in.).

Luster: Somewhat variable, ranging from dull to subvitreous. Dull in upper 2 mm (0.08 in.).

Paste-Aggregate Bond: Moderately weak; surfaces of freshly fractured concrete pass around a majority of aggregate particles.

Depth of Carbonation: Negligible along top surface.

Air Content: Estimated 1 to 3%. The concrete exhibits some small, spherical voids in the hardened paste matrix, however it does not appear intentionally air entrained.

Calcium Hydroxide*: Estimated 2 to 4% small, platy crystals of portlandite, fairly uniformly distributed throughout paste matrix and along periphery of aggregates.

Unhydrated Portland Cement Clinker Particles*: Estimated 15 to 18% unhydrated and partially hydrated portland cement clinker particles.

Supplementary Cementing Materials*: Estimated 2 to 5% residual fly ash.

Secondary Deposits: None observed.

MICROCRACKING: Several short, horizontal microcracks observed along top surface, to depths of up to 2 mm (0.08 in.). Several discontinuous, randomly-oriented microcracks also observed within body of concrete. In bottom approximate 50 mm (2.0 in.) of core, many microcracks have a tear-like appearance and often occur adjacent to, or radiating from, aggregate particles.

ESTIMATED WATER-CEMENTITIOUS MATERIALS RATIO: Moderately low to low.

MISCELLANEOUS: 1) Paste within the upper 2 mm (0.08 in.) is significantly more absorptive than paste within the body of the concrete. 2) Cementitious paste contains a moderate amount of aggregate fines.

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*percent by volume of paste

SAMPLE

Identification: #4TP.

Dimensions: Core diameter is 95 mm (3.7 in.). Core length is approximately 165 mm (6.5 in.); full slab thickness.

Top Surface: Flat, slightly rough surface exhibits light broom finish. Surface is partially coated with orange paint but appears paste-rich, medium beige-gray in color, and moderately soft. One main crack, 0.13 to 0.38 mm (0.005 to 0.015 in.) wide, extends across surface, through center of core. A second crack, approximately 0.25 mm (0.010 in.) wide, partially extends across surface from edge, generally oriented subparallel to main crack. When wetted, surface exhibits numerous, closely-spaced craze cracks.

Bottom Surface: Smooth and slightly undulating; appears as if concrete was placed on plastic sheeting. A few subparallel hairline cracks observed when surface wetted.

Cracks, Joints, Large Voids: Cracks described on top surface extend through full depth of core, passing mainly around aggregate particles and narrowing with depth to hairline width. Concrete exhibits a few fairly large entrapped air voids measuring up to 9 mm (0.35 in.) across. No joints observed.

Reinforcement: Core contains segment of one No. 4 steel reinforcing bar with approximately 90 mm (3.5 in.) of concrete cover to top surface. Bar exhibits isolated areas with minor corrosion.

AGGREGATES

Coarse: Gravel and/or partially crushed gravel composed of limestone, chert, quartzite, igneous rocks and other rocks. A small number of particles exhibit carbonate (caliche) crusts.

Fine: Natural sand composed of limestone, quartz, chert, quartzite, igneous rocks, sandstone, and other rocks and minerals.

Gradation & Top Size: Evenly graded to an observed top size of 21 mm (0.8 in.).

Shape & Distribution: Coarse– angular to sub-rounded, and mostly equant with rough to smooth surfaces; distribution is uniform. Fine– angular to rounded, and mostly equant with smooth to irregular surfaces; distribution is uniform.

PASTE

Color: Medium beige-gray. Darker beige-gray in upper 1 mm (0.04 in.).

Hardness: Moderately hard to locally moderately soft.

Luster: Subvitreous to locally dull.

Paste-Aggregate Bond: Moderately tight; surfaces of freshly fractured concrete pass both through and around aggregate particles.

Depth of Carbonation: Generally negligible along top surface.

Air Content: Estimated 1 to 3%. The concrete exhibits some small, spherical voids in the hardened paste matrix, however it does not appear intentionally air entrained.

Calcium Hydroxide*: Estimated 2 to 4% small, platy crystals of portlandite, fairly uniformly distributed throughout paste matrix and along periphery of aggregates.

Unhydrated Portland Cement Clinker Particles*: Estimated 15 to 18% unhydrated and partially hydrated portland cement clinker particles.

Supplementary Cementing Materials*: Estimated 3 to 5% residual fly ash.

Secondary Deposits: None observed.

MICROCRACKING: A few short, horizontal microcracks observed along top surface, to depths of up to 0.5 mm (0.02 in.). Several discontinuous, randomly-oriented microcracks also observed within body of concrete. Many microcracks in bottom half of core have a tear-like appearance and often occur adjacent to, or radiating from, aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Moderately low to low.

MISCELLANEOUS: 1) Paste within the upper 1 mm (0.04 in.) is somewhat more absorptive than paste within the body of the concrete. 2) Cementitious paste contains a moderate amount of aggregate fines.

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*percent by volume of paste