APPENDIX G.3

LAC+USC TUNNEL STRUCTURAL AND MECHANICAL ASSESSMENT AND ASBESTOS SURVEY,
1200 NORTH STATE STREET, LOS ANGELES, CALIFRONIA

Los Angeles County
Department of Public Works

LAC USC TUNNEL
Structural and Mechanical Assessment and Asbestos Survey

January 30, 2013

VANIR

VANIR
Construction Management, Inc.

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January 30, 2013

LA County Department of Public Works
Attention: Parisa Dadmehr
900 S. Fremont Ave., 5th Floor
Alhambra, California 91803

RE: LAC USC Tunnel Assessment

Dear Ms. Dadmehr,

Vanir Construction Management, Inc. is pleased to provide Phase II of the LAC USC Tunnel Assessment. The LAC USC Tunnel is located at 1200 North State Street, Los Angeles, California. Phase I of our assessment was provided in the report dated July 11, 2012. Our scope for Phase II included a structural and mechanical assessment of the tunnel and associated steam pipes and asbestos survey of materials within the tunnel. This work was completed by Vanir and our subconsultants; JCE Structural Engineering Group, M-E Engineers, and Focus Environmental Consultants.

The tunnel was investigated over a three day period in December during a shut-down of the utilities to allow for access to the tunnel. The area of the tunnel observed extends from the entrance on Zonal Avenue to approximately 100' inside the Juvenile Hall. Our report includes an executive summary with recommendations and the individual consultant reports provided as backup. This report provides important information regarding the safety of the tunnel and any planned or unplanned maintenance or repairs to the mechanical systems within the tunnel.

As you review our report, please feel free to contact me with any questions at 310-502-8876.

Thank you for this opportunity to be of service.

Sincerely,

Scotty Galloway, PE, CCM
Project Director

cc: Kamel Youssef
Juan Carlos Esquivel

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Background

Vanir performed a structural assessment of the (E) tunnel on the LAC USC campus between the central plant and juvenile hall. The initial investigation was conducted on June 29, 2012 in conduction with a utility shut down by the Department of Health Services. The Phase I report was provided to the Department of Public Works in a report dated July 11, 2012 (Appendix D). The results of the initial investigation resulted in a requirement for additional information including compressive strength of concrete, thickness of the concrete walls and ceiling, rebar sizing and spacing, and a corrosion study. These recommendations were all to be satisfied through an additional site visit and non-destructive testing (NDT). The intent of the future investigations was to determine the feasibility of structurally repairing the tunnel.

The Department of Public Works expanded the scope of Phase II to include a mechanical assessment of the steam pipes and asbestos survey. The team met on several occasions and participated in multiple conference calls. There were safety concerns identified during Phase I that would be required to be addressed prior to the Phase II tunnel entry. The tunnel was a permitted confined space and suspected asbestos containing material site to include friable materials. The tunnel was required to be ventilated and cooled off prior to entering, it was not safe to enter “immediately” due to the extreme heat.

The team worked with DPW and DHS to gain entry into the tunnel for a three day period from December 7-9, 2012. Over the three day site investigation, the structural, mechanical, and environmental evaluation team entered the tunnel numerous times in Level C PPE. They evaluated the tunnel from Zonal Avenue to the inside of the Juvenile Hall to the extent that they could not penetrate the tunnel any farther.

Structural Assessment

JCE Structural Engineering Group was responsible for making the tunnel safe for entry on December 7, 2012 and maintained attendants for the confined space for the duration of the operation. The complete structural assessment is included as Appendix A. JCE performed structural evaluations December 7-9 in conjunction with their subconsultant Vector Corrosion Technologies. The structural assessment team performed visual observations, core testing, ground penetrating radar, and corrosion analysis.

The tunnel has visible deterioration throughout. The concrete is delaminating on the ceilings and walls exposing corroded reinforcing bars. Approximately 25% of the tunnel ceiling has completely spalled off its concrete cover exposing the reinforcing. The reinforcing is corroded, broken, or missing. The walls of the tunnel demonstrate severe efflorescence and damage due to the sulfate attacks. Corrosion testing indicates more than 90% of the reinforcing in the areas tested are actively corroding or are at risk of corrosion. The concrete is described as “soft” in many areas and crumbles when scraped with a steel tool.

The remaining service life of the tunnel is expected to be less than five years.

Mechanical Assessment

M-E Engineers entered the tunnel on Sunday, December 9, 2012 to evaluate the existing steam piping system “ON” and “OFF” and identify and deficiencies and maintenance issues. The complete mechanical assessment is included as Appendix B. The steam is being generated in the Central Utility Plant and distributed in the subject tunnel to the Juvenile Hall, ISD Blue Mill Building, and Raid Schneider Building. The system consists of one supply pipe, two condensate return pipes, and one electrical conduit. The steam is used to provide building heat and domestic hot water facilities it serves.

The overall system is in poor condition. The pipes are rusted and leaking, the insulation is falling apart, and the pipe hangers are not properly anchored to the concrete wall as a result of the deteriorating concrete. The supply and return lines are in poor working condition and have a high potential of failure. There is steam leaking in many areas and can be visibly identified at street level outside the tunnel. The insulation is poor and missing many locations. The report indicates no condensate was being returned to the CUP. In addition to the safety and risk of failure to the system, the system is very inefficient due to the leaking pipes and lack of insulation. The inefficiency of the existing system should be considered in any financial analysis of recommended actions.

Asbestos Survey

Focus Environmental Consulting entered the tunnel on Friday, December 7, 2012 to collect samples from the materials in the tunnel and identify the Asbestos Containing Material (ACM). The complete asbestos survey is included as Appendix C. Bulk samples of all suspect ACM materials were taken. The samples were sent to a lab and analyzed using the PLM technique. A total of fourteen (14) samples of suspect ACM were collected for analysis during the survey. Eight samples positively identified the material as ACM. The black wall joint sealant on the tunnel walls was determined to be non-friable asbestos occurring over approximately 80 joints. The TSI pipe insulation is friable asbestos (Amosite and Chrysolite) in fair condition and occurs throughout the length of the tunnel on the steam pipes. The TSI Pipe Elbows and Concrete Skim Coat resulted in “ND” (none detected).

Regulations require that any time ACM’s are impacted during repair, renovation, removal, or demolition that the work be performed by properly trained and certified workers. This must be considered in when implementing any of the alternatives provided in this report.

Recommendation

The recommendations provided herein are based on the compilation of all three reports. While each report has its own recommendations, they are provided without consideration of the other reports.

Based on the structural evaluation and rapidly deteriorating physical properties of the concrete due to the high levels of sulfate, there should not be *any* entry into the tunnel for repairs or evaluation without the installation of a shoring system. It is recommended that the County prevent vehicles from parking in the footprint directly above the existing tunnel. This is intended to mitigate further collapse of the tunnel and minimize the possibility of damage to people and property on the ground level as a result of tunnel collapse. Upon decommissioning of the steam system, the tunnel should be filled with a slurry and abandoned.

The mechanical recommendation is to provide natural gas-fired high efficiency water boilers for space heating and water heaters for domestic hot water at the location of the buildings served. In the event that any of the facilities need steam, local electric steam generators can be provided. This should be coordinated with the campus master plan; however, due to the condition of the existing pipes and tunnel it is recommended to complete this installation within two years.

The recommendation to repair leaking pipes and insulation appears to be cost prohibitive. The recommendation would require the shoring of sections of the tunnel by personnel certified to work with asbestos, abatement of sections of the insulation, and installation of the new insulation or repair of the leak. However, this remains an option.

The County should begin immediately planning for alternative methods to provide building heat and domestic hot water to the served buildings in the event of a system failure. In the event of a failure, an immediate response to repair the issue would not be available due to the issues identified above. Additionally, the service life of the tunnel is less than five years as a result of the sulfates.

JCE STRUCTURAL ENGINEERING GROUP, INC.

Structural Assessment & Corrosion Evaluation Of LAC+USC Medical Center/Utility Tunnel (Juvenile Hall)

Los Angeles, California

Prepared for:
Vanir Construction Management
&
County of Los Angeles DPW

By:
Juan Carlos Esquivel, M.S., S.E.

JCE JOB NO: 2012.037.2

January 21, 2013

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REGISTERED PROFESSIONAL ENGINEER
JUAN CARLOS ESQUIVEL
No. S 4074
Exp. 6-30-14
STRUCTURAL
STATE OF CALIFORNIA

EXECUTIVE SUMMARY

A Structural assessment of the LAC – USC Medical Center / Utility Tunnel (Parking structure-Juvenile Hall) was carried out by **JCE Structural Engineering Group** between December 7th and 9th, 2012.

As part of the Structural Assessment and based on our first report recommendations dated July 11, 2012, a series of Non-Destructive Testing and a Corrosion Evaluation study was also performed during those three days.

As part of the Non-Destructive Test Program, concrete cores and GPR Survey (Ground Penetrating Radar) was performed to determine the compressive strength, chemical analysis and petographic examination of the concrete walls and ceilings as well as to determine the (E) rebar sizes, spacing, locations and cover. We also requested to have half cell potential survey to determine the extent of the rebars' corrosion as well as the remaining life of the tunnel.

This information was used to perform a preliminary structural evaluation of the capacity of the (E) tunnel when it was constructed to have an idea of the Demand/Capacity ratio and adequacy of the (E) tunnel at the time of construction, as well as to perform an “if scenario” of a possibly strengthening tunnel option..

From reviewing the demand required by the (E) tunnel to be able to support the loads coming from the soil above the tunnel, parking loads above and dynamic soil effects during any Earthquake event, it is clearly evident that in order to repair the tunnel a shotcrete solution needs to be implemented. (See Appendices A & B). The shotcrete solution basically consists of adding a new 8” (minimum) up to 12” layer of concrete with #5@ 12”o.c. rebars all around and with #4 dowels @ 8”o.c. as shown on our Appendix A. This solution will be applicable for almost 30% of the length of the tunnel.

In some areas (perhaps another 50% of the length of the tunnel) a layer of Fiberwrap or any similar product could be used to keep the retrofit Thinner and less invasive, but unfortunately since a large portion of the tunnel needs to be shotcreted and in order to have the steam pipes aligned the (E) tunnels will be greatly reduced in size (width and depth) making this solution logistically unfeasible. See inside for more discussion.

Based on our job site investigation, results of NDT, Corrosion Evaluation and structural preliminary calculations, the following are the options studied.

- Option #1 – Repair the tunnel and the steam pipes and insulation.
- Option #2 – Abandon the tunnel and fill it with slurry concrete (f’c=3,000 psi min).

From our analysis of the Pros and Cons of both options (See discussions on item 6 inside) above we definitely recommend **Option #2.**

1. INTRODUCTION

JCE Structural Engineering Group, Inc. was contracted to perform a Phase 2 of the Structural Assessment of the structural conditions of an (E) Concrete Utilities Tunnel referred as Juvenile Hall Tunnel in this report. An initial first Phase Report was dated July 11, 2012.

As part of the Phase 2 Structural Assessment, JCE Structural Engineering Group hired Vector Corrosion Technologies as their Sub-consultant to provide a NDT (Non-Destructive Testing) Program as well as a corrosion evaluation to assess the concrete conditions of the (E) tunnel material and to evaluate the remaining life expectance of the tunnel as it was recommended on Phase 1 Report.

2. TUNNEL DESCRIPTION

The South Side of the Juvenile Hall Tunnel was originally constructed approximately in 1930’s (more than 80 years old). The dimensions of the (E) tunnel are approximately 4’-0” wide by 6’-0” high and is made of reinforced concrete walls & ceiling. From the NDT investigation we have determined that the wall and ceiling of the tunnels are made of 6” concrete with 2 layers of #3 rebars spaced @ 8”o.c vertically and @14’ o.c. horizontally.

3. WORK METHODOLOGY

JCE Structural Engineering Group, represented by Juan Carlos Esquivel, M.S., S.E., together with **Vector Corrosion Technologies** represented by Andrew Broecker and Clarence Zimmel, NACE CP2 Cathodic Protection Technicians, performed a three day site observation and investigation of the entire accessible part of the tunnel from Zonal Avenue to approximately 100 ft inside the Juvenile Hall.

During the three days site observation and inspection the following tasks were performed:

- Structural visual assessment and delimitation survey of the entire accessible portion of the tunnel by Juan Carlos Esquivel, M.S., S.E., Principal of JCE Structural Engineering Group and Andrew Broecker and Clarence Zimmel from Vector Corrosion Technologies. The tunnel was NOT accessible beyond Zonal Avenue (See Photo 1) up to about 100 feet into the Juvenile hall (See Photos 2 & 3).

- Core testing at two main locations (4 cores total) (agreed between JCE Structural Engineering Group and Vector Corrosion Technologies after our initial visual assessment and delimitation survey) as the most representative areas of damaged and undamaged portions of the (E) tunnel.

- GPR (Ground Penetration Radar) survey to determine rebars size, spacing locations and cover.

- Gathering information (Photos, measurements, etc.) of the entire tunnel length to determine the different levels of damage to propose any structural restrengthening alternatives. See Photos 4 to 25 of the several operations during the three days.

4. OBSERVATIONS

From our three days visual inspection of the current structural conditions of the (E) Tunnel, we have observed and been able to quantify the following:

- At many locations (about 25% to 30% of the total length of the accessible tunnel) the ceiling of the tunnel has been completely delaminated and spalled. Many of the reinforcing bars are exposed, severely corroded & in many instances have lost most of their sections or are completely broken. See photos 26 to 31. This estimate is consistent with Vector Corrosion Technologies report attached as an appendix of this report.

- At many other locations (through the whole length of the tunnel) the ceiling of the tunnel shows severe signs of delamination and large cracks and the concrete is ready to be spalled. This is a clear indication that reinforcing inside the concrete ceilings have been severely corroded. See photos 32 to 35.

- At many wall locations (approx. 40% more) the concrete has also spalled and there are many corroded and exposed reinforcing bars shown. Many of them show severe reduction of their original section, some of them are bent and others are completely broken. See photos 36 to 50.

- At many wall locations (through the whole length of the tunnel) there are severe signs of efflorescense on the walls and ceiling indicating concrete being damage inside and ready to eventually spalled off due to severe sulfate attack. See photos 51 to 68.

- At many locations the steam pipe supports are completely rusted and not properly anchored to the concrete. See Photos 69 to 75.

5. NDT AND CORROSION EVALUATION RESULTS DISCUSSION

From the NDT and corrosion study performed by Vector Corrosion Technologies, the following items are the main discoveries.

- Half-cell potential indicate that more than 90% of the reinforcing in the tested areas is either actively corroding or is at risk of corrosion.

- The pH of the concrete has been reduced to pH <8.25 throughout the cross section in all areas tested, indicating exposure to external sulfate attack.

- The concrete in “Bad” areas is suffering from an advanced stage of sulfate attack.

- The concrete is soft in many areas and crumbles when scraped with a steel tool.

- The design compressive strength is approximately 3500 to 4000 psi.

- The remaining service life of the existing tunnel is most likely less than 5 years due to the progressive nature of the sulfate attack.

See appendix D for more in-depth results of the corrosion evaluation.

6. STRUCTURAL STRENGTHENING REPAIR DISCUSSIONS & RECOMMENDATIONS

In our previous first draft report we recommended to consider the following two options:

Option 1:

A) Structural Strengthening Repair of the (E) tunnel.

- In order to evaluate the strengthening repair possibilities of the (E) tunnel, we recommended an NDT program to be performed first to determine the (E) concrete strength, (E) concrete ceiling and wall thickness, (E) rebars size, spacing and location, to be able to determine the original structural capacity of the (E) tunnel. We also recommended a corrosion evaluation to determine other areas of potential corrosion besides the obvious ones as well as the life expectancy of the (E) tunnel. Based on the results of the NDT program, the results of the structural capacity of the (E) tunnel, and the corrosion evaluation, a combination of shotcrete and Fiberwrap strengthening methodologies were considered.

  Unfortunately, although perhaps 30% of the length of the tunnel could be strengthened with the use of Fiberwrap, about 25% to 30% of the length of the tunnel needs at least to be shotcreted. Moreover, although some of the compressive strength of the concrete had good results, in the majority of those areas the rebars are under current heavy corrosion attack. In order to perform strengthening with Fiberwrap or shotcrete all the (E) steam pipes should need to be removed first and then re-installed. Since the amount of shotcrete to add is a minimum of 8” to perhaps 12” thick and the pipes have to be aligned along the full length of the wall the interior available space of the (E) tunnel will be reduced by 16” to 24” in width and 8” to 12” in height making logistically very difficult to reinstall the steam pipes and more over to maintain/service them in the future. See Photos 76 to 84 for tightness of the current space available.

- Another disadvantage for restrengthening the (E) tunnel is the Steam shutdown time to repair the tunnel and remove and re-install the new steam pipes which can be months of building operation.

Option 2:

B) Relocate the low pressure steam piping and burry the tunnel

Obviously this solution seems to be the most cost effective and will resolve problems such as : Safety inside the tunnel as well as safety of the cars and passengers parking on the structure above the footprint of the (E) tunnel. See Photos 85 to 87 showing the damaged stage of the Parking structure above the (E) tunnel.

- A brief summary table of the two options explored with Pros and Cons is presented below:

Options	Pros	Cons
Option 1: Strengthening the tunnel	Keep the tunnel	- Most likely cost prohibitive (the cost of the cathodic protection "only" is between $300,000 to $400,000. This does not include the cost of the 8" to 12" shotcrete) - Months of shutdown building operations - Logistically difficult to reinstall steam pipes - Logistically difficult to provide services to the steam pipes in the future due to tight access.
Option 2: Abandon the Tunnel	- Most likely less expensive than Option 1. - Safety issues with Parking structure above resolved - Safety Hazard issues inside the tunnel resolved.	- Parking spaces above shall be limited while the tunnel is being filled with slurry concrete but this is the case for both options.

One of the Main problems discovered during our job site investigation is also that the area of the tunnel that has severely ceiling and wall damage is right underneath a good portion of the existing and currently being used parking structure above.

It is our professional opinion based on our experience and as it is clearly shown on the Pros and Cons table above, to highly recommend Option 2. We also would like to recommend informing LAUSC of the need to stop parking vehicles above the footprint of the (E) tunnel to prevent any possible further collapse of the tunnel with consequences on the cars parked above the area until the tunnel is filled with slurry concrete as recommended in Option 2 above.

7. DISCLAIMER

Our professional services have been performed with the intent to meet the degree of care and skill ordinarily exercised by reputable Structural Engineers practicing in this or similar localities and under similar conditions. No other warranty, expressed of implied, is made as to the professional advice or opinions included in this report.

8. REFERENCES

A. Evaluation Of The Utility Tunnels Report by Bock Engineering, Inc. dated July 25, 2003.
B. Section 3 - Existing Tunnel Systems from Ralph M. Parsons Company report done in 1975.
C. Sheet dwg Nos R676-1, R676-2, R676-3 & R676-4 by Ralph M. Parsons Company, dated 1975.
D. Concrete Corrosion Evaluation by Vector Corrosion Technologies, Dated Jan 8, 2013

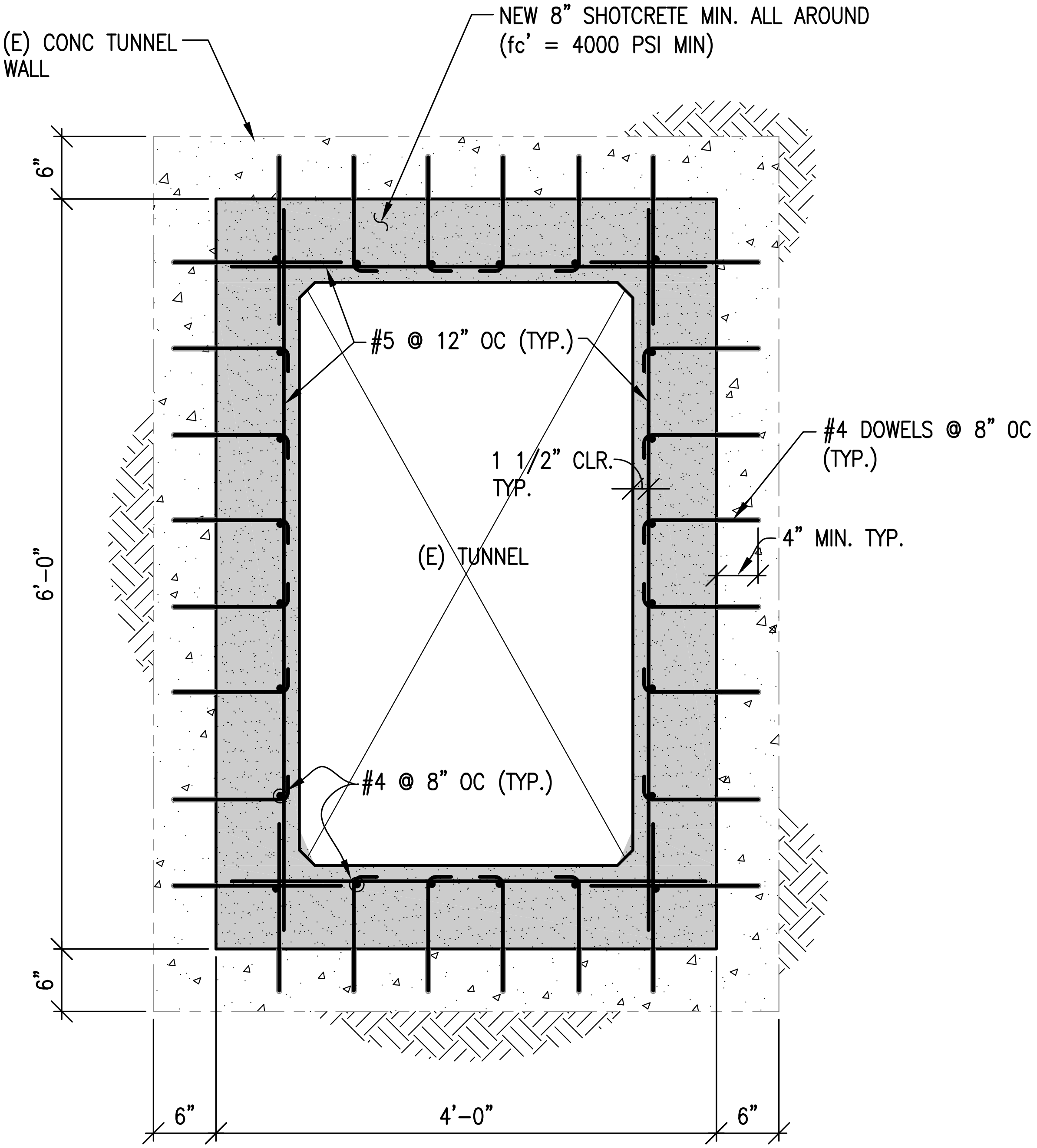
9. APPENDICES

APPENDIX A. STRENGTHENING DETAIL
APPENDIX B. PRELIMINARY STRUCTURAL CALCULATION
APPENDIX C. FIGURE & PHOTOS
APPENDIX D. CONCRETE CORROSION EVALUATION REPORT

APPENDICES

APPENDIX A

STRENGTHENING DETAIL



NEW SHOTCRETE FOR (E) TUNNEL

3/4"=1'-0"

JCE STRUCTURAL ENGINEERING GROUP, INC.
STRUCTURAL & EARTHQUAKE ENGINEERING CONSULTANTS
234 E. Colorado Blvd., Suite 725, Pasadena, CA 91101-2225 Tel: (626) 585-1822 Fax (626) 585-1824

PROJECT:
LAC+USC MEDICAL CENTER
(E) UTILITY TUNNEL

PROJECT No.
2012.037

DATE:
JANUARY 21, 2013

ENGINEER:
JUAN CARLOS ESQUIVEL, M.S., S.E.

SHEET No.
SSK-1
17

APPENDIX B

PRELIMINARY STRUCTURAL CALCULATIONS

JCE STRUCTURAL ENGINEERING GROUP, INC.

LAC+USC MEDICAL CENTER
UTILITY TUNNEL
JUVENILE HALL

LOS ANGELES, CA 90033

STRUCTURAL CALCULATIONS

REGISTERED PROFESSIONAL ENGINEER
JUAN CARLOS ESQUIVEL
No. S 4074
EXP. 6-30-14
STRUCTURAL
STATE OF CALIFORNIA

Prepared for:
VANIR CONSTRUCTION MANAGEMENT

Prepared By:
Juan Carlos Esquivel, M.S.,S.E.

JCE JOB NO: 2012.037.1

January 18, 2013

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ANALYSIS CRITERIA AND CONCLUSION

1. CODES & REFERENCES

A. Governing Codes

1. California Building Code -2010 Edition
2. American Concrete Institute – ACI 318-08

2. SCOPE OF WORK

Existing Structural Analysis for underground 4'-6" wide x 6'-4" tall (CTC) concrete tunnel.
Member thickness = 6 inch on top slab, side walls and foundation slab.

3. MATERIALS

(E) Concrete

fc'= 4000 psi

(E) Rebar

fy= 40 ksi

4. ANALYSIS CRITERIA

a.	Soil Weight (Assumed):	110	pcf
b.	At Rest Souil Equivalent Fluid Pressure	55.0	pcf
c.	Soil above tunnel:	12.0	ft
d.	Weight of Soil above Tunnel (1.15 arching):	1.52	kips/ft
e.	Parking surcharge: (Not for Embed > 9 ft)	0	psf
f.	Lateral Pressure from Surcharge:	0	psf
g.	Sds:	1.471	
h.	Seismic Lateral Soil Pressure (Uniform):	360	psf

5. ANALYSIS RESULT

a. Existing Tunnel

All Demand to Capacity Ratios are greater than 1.0. This Tunnel is Overstressed under Analysis Criteria. All Demands are from Sap2000 Analysis.

Item	Mu (k-ft/ft)	ϕMn	DCR
a. Top Slab	5.3	2.35	**2.26**
b. Side Walls	5.9	2.35	**2.51**
c. Bottom Slab	5.9	2.35	**2.51**

b. New Shutcrete

New 8" shutcrete added to take all positive momentswithout all existing bars. All DCR < 1.0. OK.

Item	Mu (k-ft/ft)	ϕMn	DCR
a. Top Slab	5.22	8.23	**0.63**
b. Side Walls	7.63	8.23	**0.93**
c. Bottom Slab	4.6	8.23	**0.56**

C:\Andrew\1 Proj\Misc\2012.037 USC Unti Tunnel\[JCE CoverSht Div Calc Pad4e.xls]NE

2010 CBC / 2009 IBC / ASCE7-05 11.4.4 Design Spectral Acceleration

USGS EARTHQUAKE HARZARD PROGRAM 'USGS Java Earthquake Ground Motion Parameters V6" Output :

```
Conterminous 48 States
2009 International Building Code
Latitude = 34.059776
Longitude = -118.20986200000002
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B -  Fa = 1.0 ,Fv = 1.0
Data are based on a 0.01 deg grid spacing
  Period    Sa
  (sec)    (g)
   0.2    2.207 (Ss, Site Class B)
   1.0    0.763 (S1, Site Class B)


Conterminous 48 States
2009 International Building Code
Latitude = 34.059776
Longitude = -118.20986200000002
Spectral Response Accelerations SMs and SM1
SMs = Fa x Ss and SM1 = Fv x S1
Site Class D -  Fa = 1.0 ,Fv = 1.5

  Period    Sa
  (sec)    (g)
   0.2    2.207 (SMs, Site Class D)
   1.0    1.145 (SM1, Site Class D)


Conterminous 48 States
2009 International Building Code
Latitude = 34.059776
Longitude = -118.20986200000002
Design Spectral Response Accelerations SDs and SD1
SDs = 2/3 x SMs and SD1 = 2/3 x SM1
Site Class D -  Fa = 1.0 ,Fv = 1.5

  Period    Sa
  (sec)    (g)
   0.2    1.471 (SDs, Site Class D)
   1.0    0.763 (SD1, Site Class D)
```

1200 N State Street, Los Angeles, CA 90033

N	34.0598	Latitude
E	-118.21	Longitude

SS= 2.207
S1= 0.763

SDS= 1.471
SD1= 0.763

Concrete Capacity

Concrete strength: $f'_c := 4000\text{psi}$

Rebar strength: $f_y := 40\text{ksi}$

(E) Wall (6" thick)

Concrete thickness: $t := 6\text{in}$ per $b := 1\text{ft}$

Concrete cover: $c := 1\text{in}$

#3 Horizontal @ 8" o.c. $d_{bar} := 0.375\text{in}$ $s := 8\text{in}$

Area of steel: $A_s := \left(\frac{d_{bar}}{2}\right)^2 \cdot \pi \cdot \left(\frac{12\text{in}}{s}\right)$ $A_s = 0.166\ \text{in}^2$

Rebar depth: $d := t - c - 0.5d_{bar}$ $d = 4.812\ \text{in}$

Moment capacity $\phi := 0.90$ $\phi M_n := \phi \cdot A_s \cdot f_y \cdot \left[d - \left(\frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b}\right) \cdot \frac{1}{2}\right]$ $\boxed{\phi M_n = 2.351\ \text{kip} \cdot \text{ft}}$

Shear capacity $\phi := 0.75$ $\phi V_n := \phi \cdot \left(2 \cdot \sqrt{f'_c \cdot \text{psi}} \cdot d \cdot b\right)$ $\boxed{\phi V_n = 5.479\ \text{kip}}$

#3 horizontal@ 14" o.c. $d_{bar} := 0.375\text{in}$ $s := 14\text{in}$

Area of steel: $A_s := \left(\frac{d_{bar}}{2}\right)^2 \cdot \pi \cdot \left(\frac{12\text{in}}{s}\right)$ $A_s = 0.095\ \text{in}^2$

Rebar depth: $d := t - c - 0.5d_{bar}$ $d = 4.812\ \text{in}$

Moment capacity $\phi := 0.90$ $\phi M_n := \phi \cdot A_s \cdot f_y \cdot \left[d - \left(\frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b}\right) \cdot \frac{1}{2}\right]$ $\boxed{\phi M_n = 1.354\ \text{kip} \cdot \text{ft}}$

Shear capacity $\phi := 0.75$ $\phi V_n := \phi \cdot \left(2 \cdot \sqrt{f'_c \cdot \text{psi}} \cdot d \cdot b\right)$ $\boxed{\phi V_n = 5.479\ \text{kip}}$

Concrete strength: $f'_c := 4000psi$

Rebar strength: $f_y := 60ksi$

NEW Wall (8" thick)

Concrete thickness: $t := 8in$ per $b := 1ft$

Concrete cover: $c := 2in$

#5 Horizontal @ 12" o.c. $d_{bar} := 5 \div 8in$ $s := 12in$

Area of steel: $A_s := \left(\frac{d_{bar}}{2}\right)^2 \cdot \pi \cdot \left(\frac{12in}{s}\right)$ $A_s = 0.307\ in^2$

Rebar depth: $d := t - c - 0.5d_{bar}$ $d = 5.688\ in$

Moment capacity $\phi := 0.90$ $\phi M_n := \phi \cdot A_s \cdot f_y \cdot \left[d - \left(\frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b}\right) \cdot \frac{1}{2}\right]$ $\boxed{\phi M_n = 7.541\ kip \cdot ft}$

Shear capacity $\phi := 0.75$ $\phi V_n := \phi \cdot \left(2 \cdot \sqrt{f'_c \cdot psi} \cdot d \cdot b\right)$ $\boxed{\phi V_n = 6.475\ kip}$

Concrete strength: $f'_c := 4000psi$

Rebar strength: $f_y := 40ksi$

#3 horizontal@ 8" o.c. $d_{bar} := 0.375in$ $s := 8in$

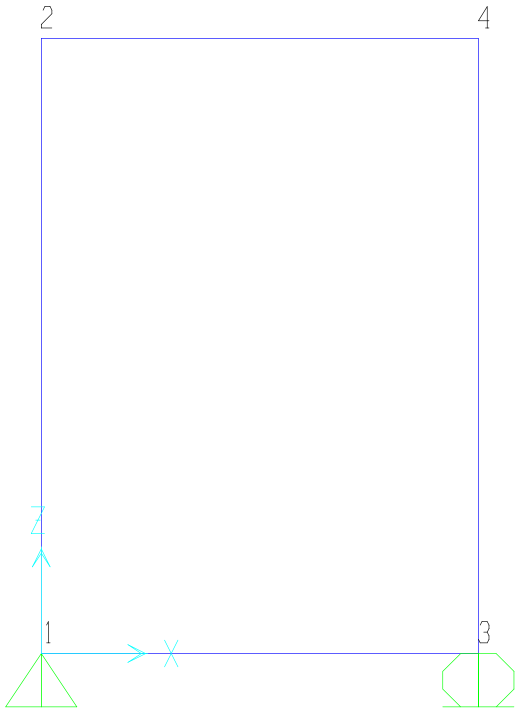
Area of steel: $A_s := \left(\frac{d_{bar}}{2}\right)^2 \cdot \pi \cdot \left(\frac{12in}{s}\right)$ $A_s = 0.166\ in^2$

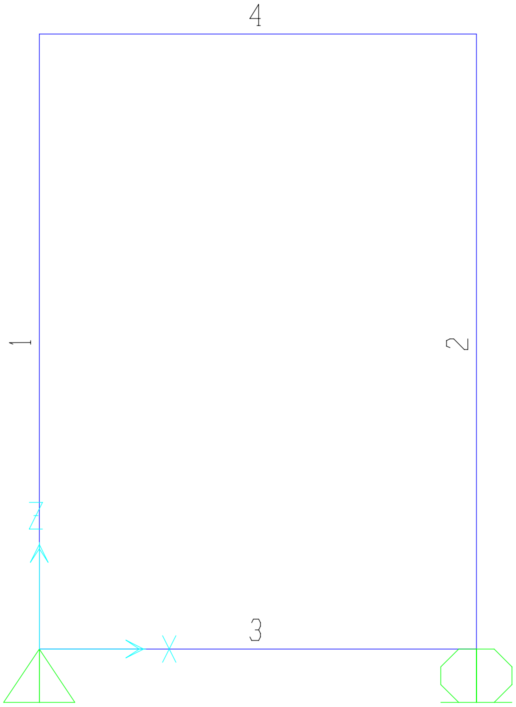
Rebar depth: $d := t - c - 0.5d_{bar}$ $d = 5.813\ in$

Moment capacity $\phi := 0.90$ $\phi M_n := \phi \cdot A_s \cdot f_y \cdot \left[d - \left(\frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b}\right) \cdot \frac{1}{2}\right]$ $\boxed{\phi M_n = 2.849\ kip \cdot ft}$

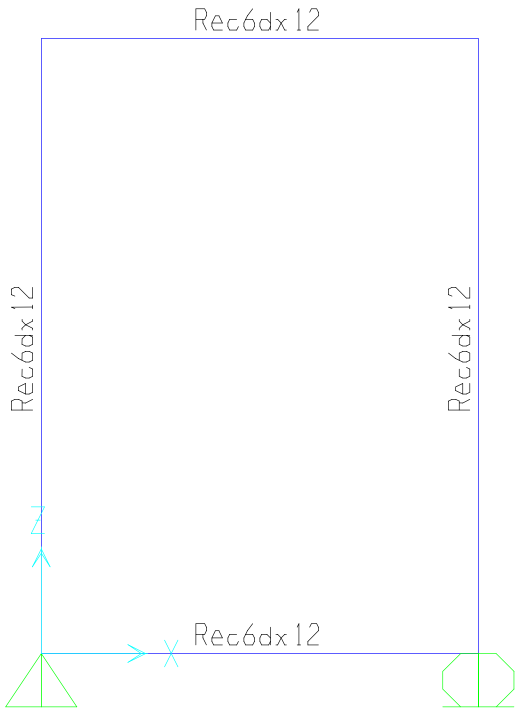
Shear capacity $\phi := 0.75$ $\phi V_n := \phi \cdot \left(2 \cdot \sqrt{f'_c \cdot psi} \cdot d \cdot b\right)$ $\boxed{\phi V_n = 6.617\ kip}$

EXISTING TUNNEL ANALYSIS: SAP2000 RESULTS


2
4
Z
1
X
3



PAGE: 10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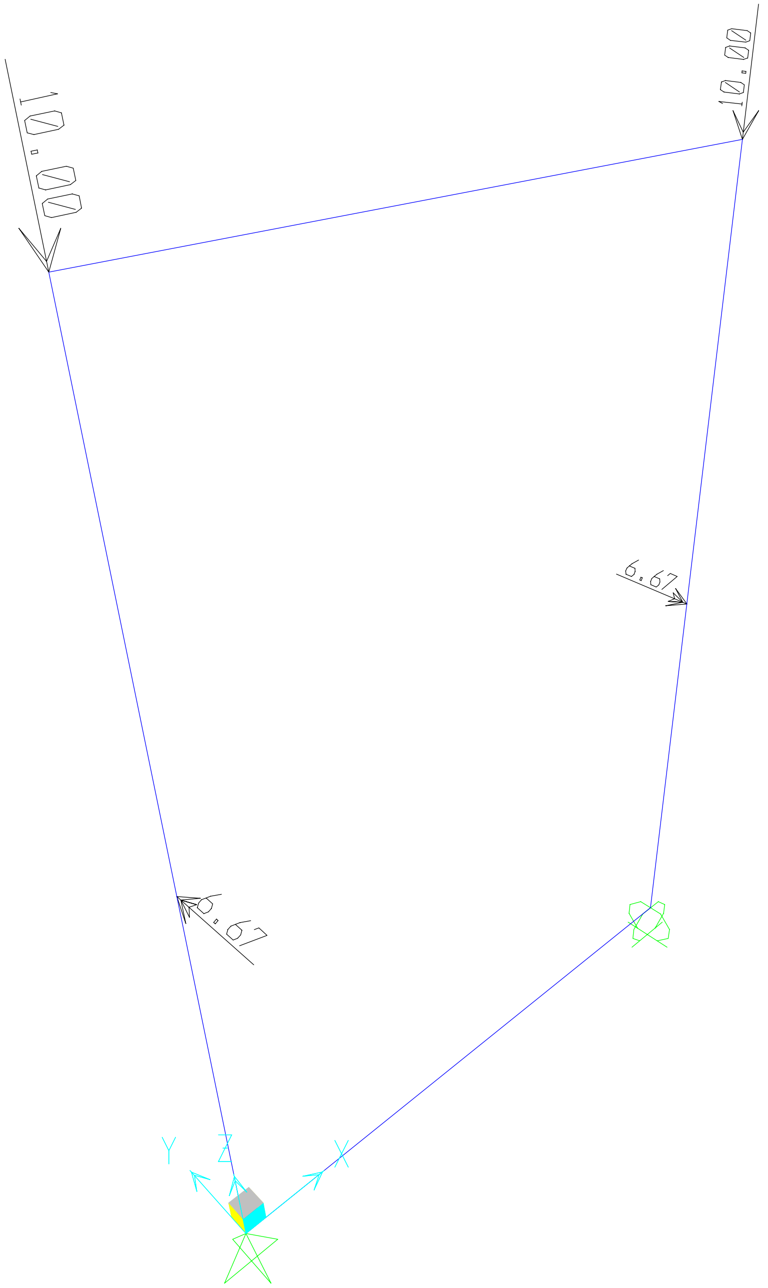
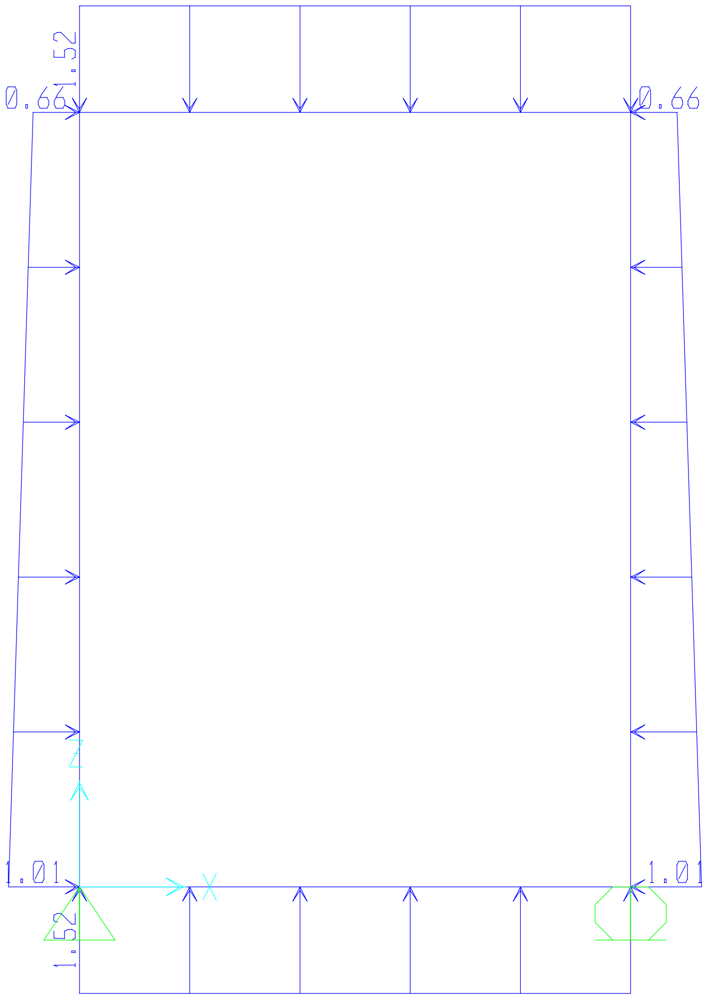
Rec6dx12
Rec6dx12
Z
X
Rec6dx12



SAP2000 v15.0.0 - File:box4x6_no L - Frame Span Moments (DEAD) (As Defined) - lb, ft, F Units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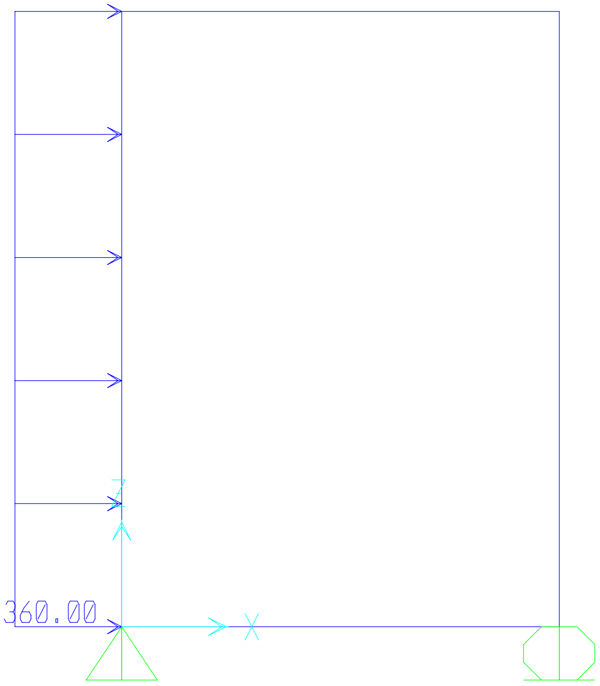
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Z
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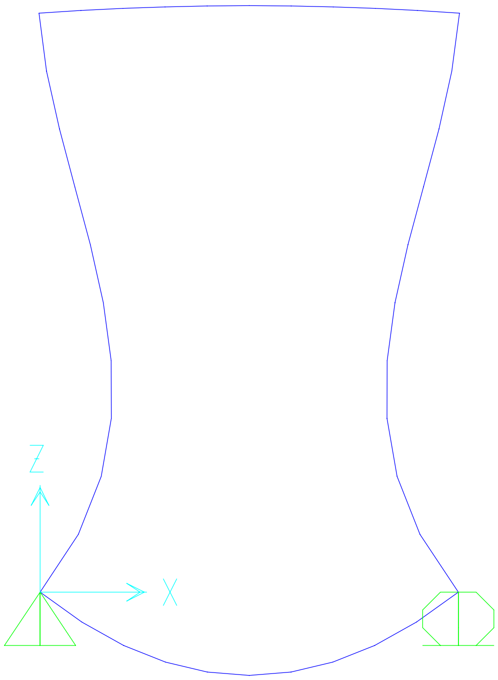
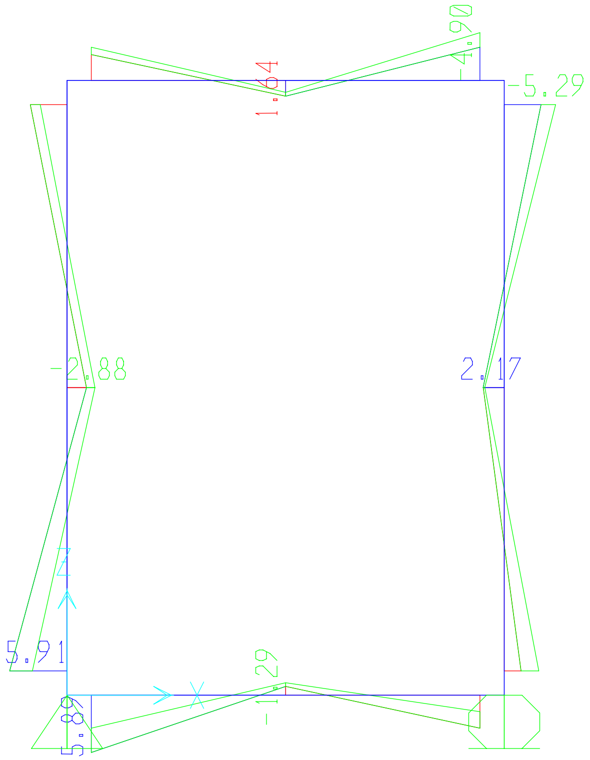


SAP2000 v15.0.0 - File:box4x6_no L - Deformed Shape (DLH) - Kip, in, F Units



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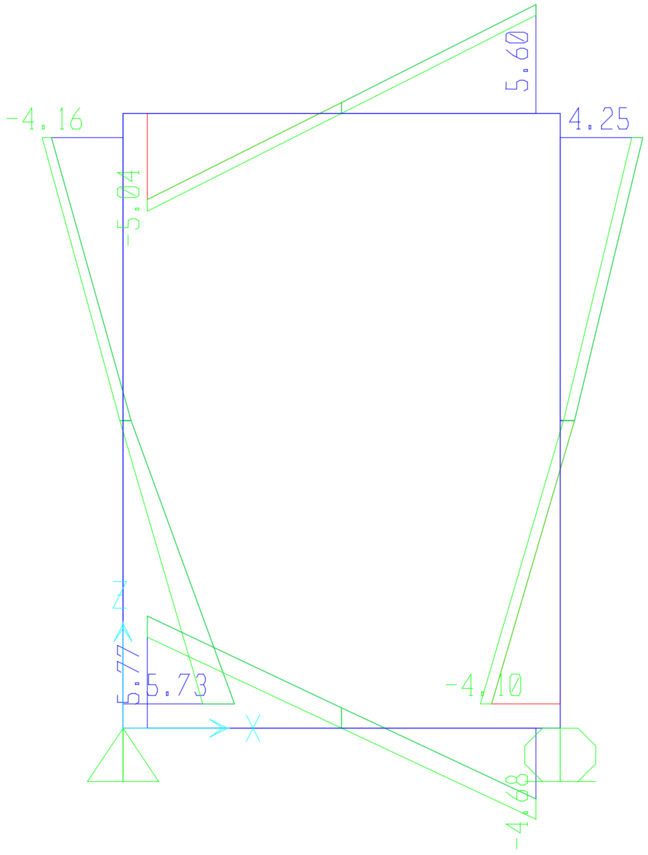
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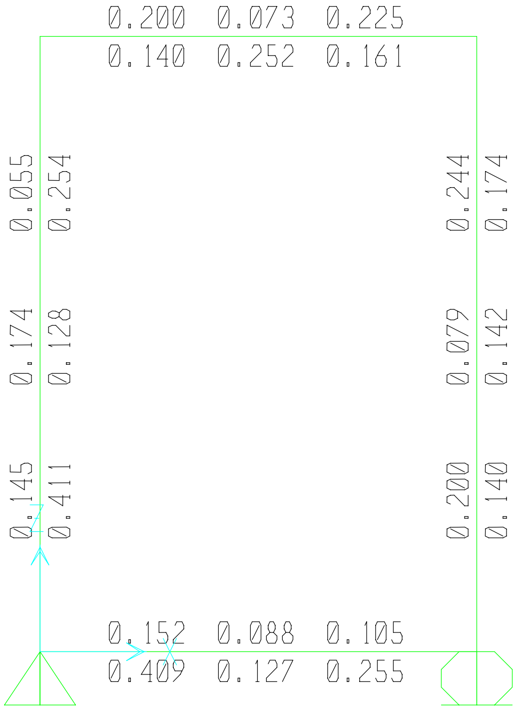
-5.04
Z
5.77
5.73
X
-4.10
-4.68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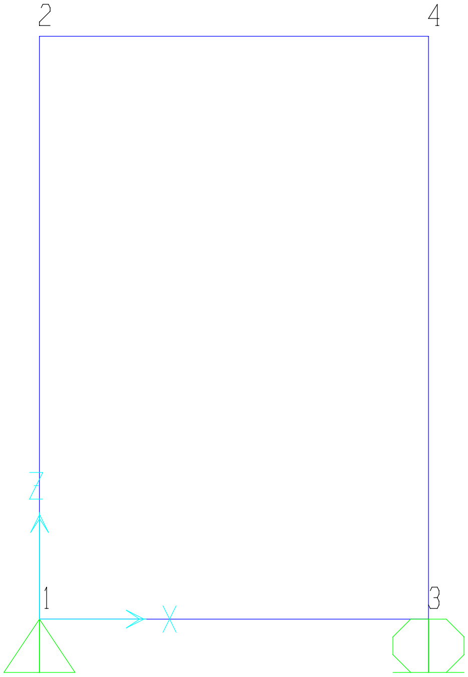
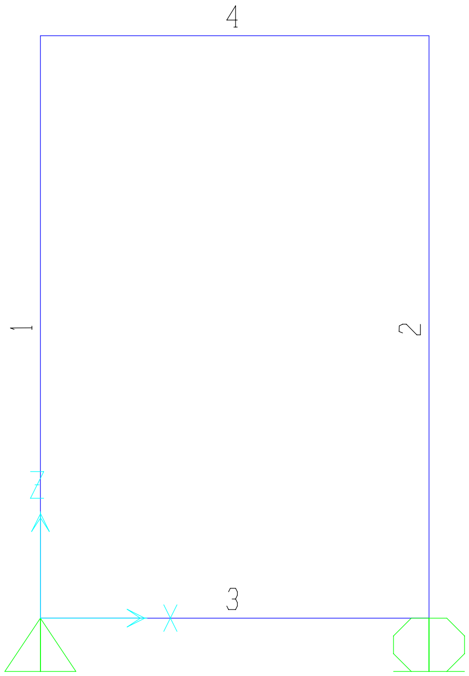
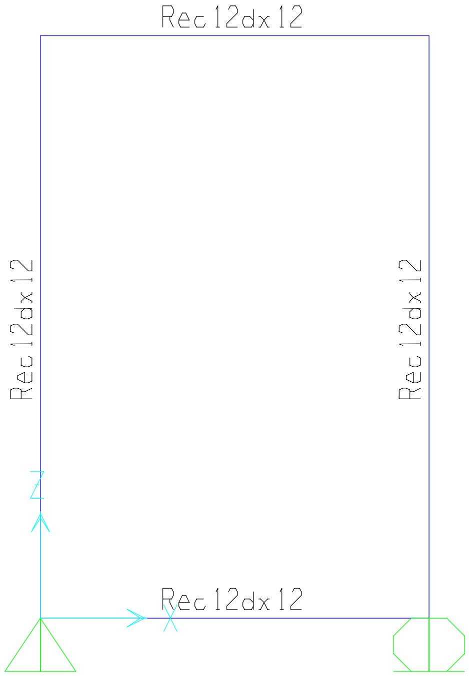
0.225
0.140
0.252
0.161
0.055
0.254
0.174
0.128
0.145
0.411
0.244
0.174
0.079
0.142
0.200
0.140
0.152
0.088
0.105
0.409
0.127
0.255
Z
X

NEW TUNNEL ANALYSIS: SAP2000 RESULTS


2
4
Z
1
X
3


4
1
2
Z
X
3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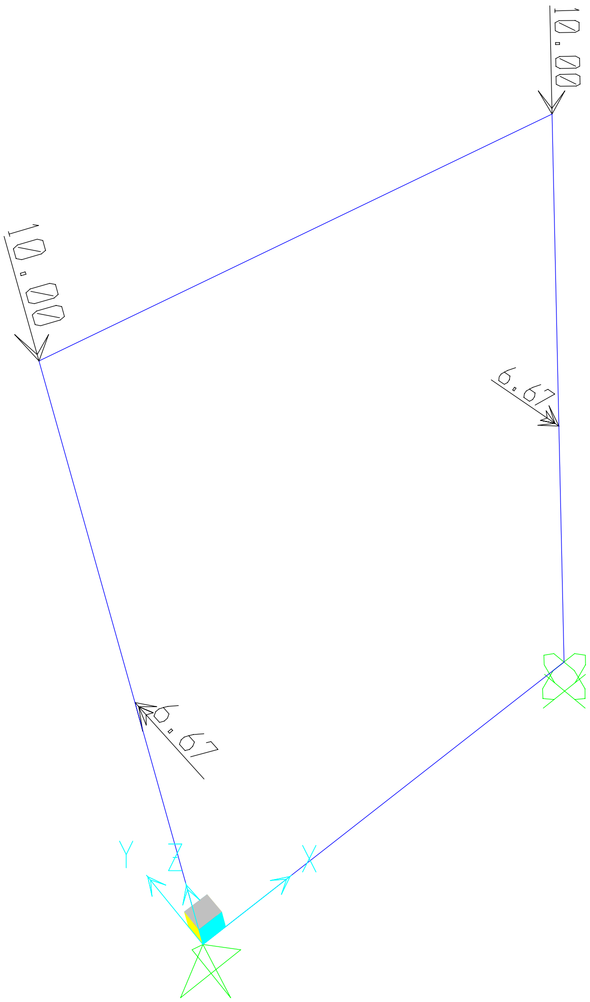
Rec12dx12
Rec12dx12
Rec12dx12
Z
X



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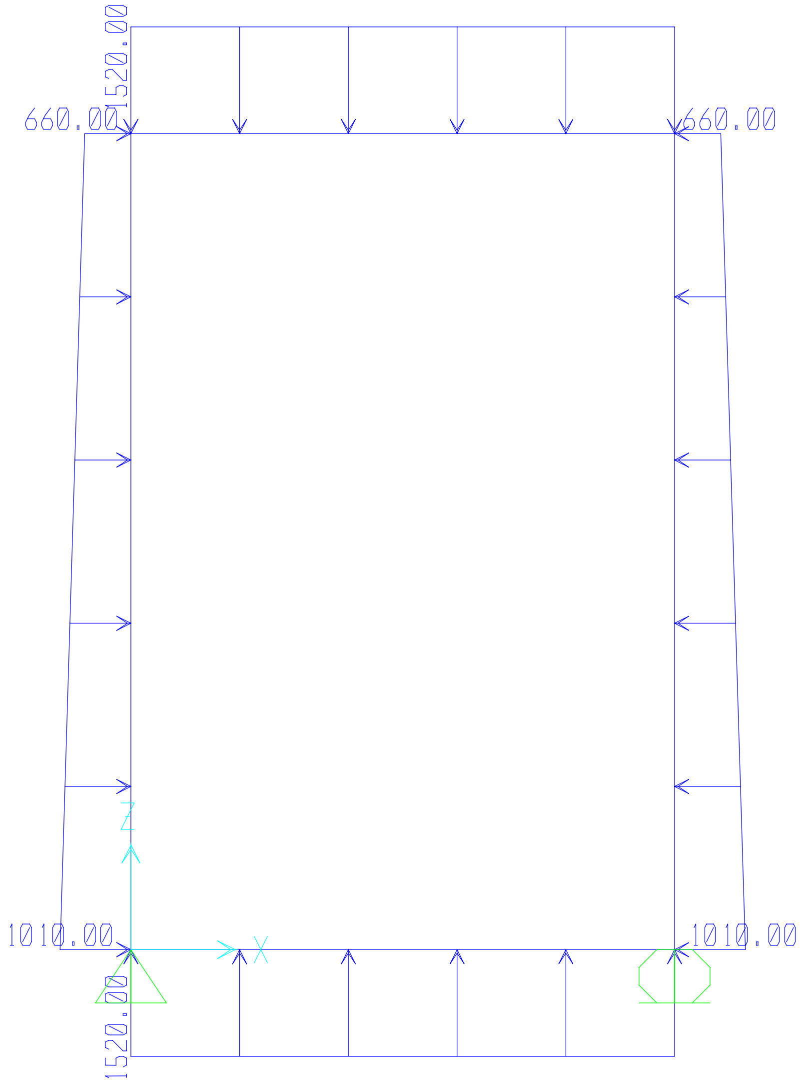
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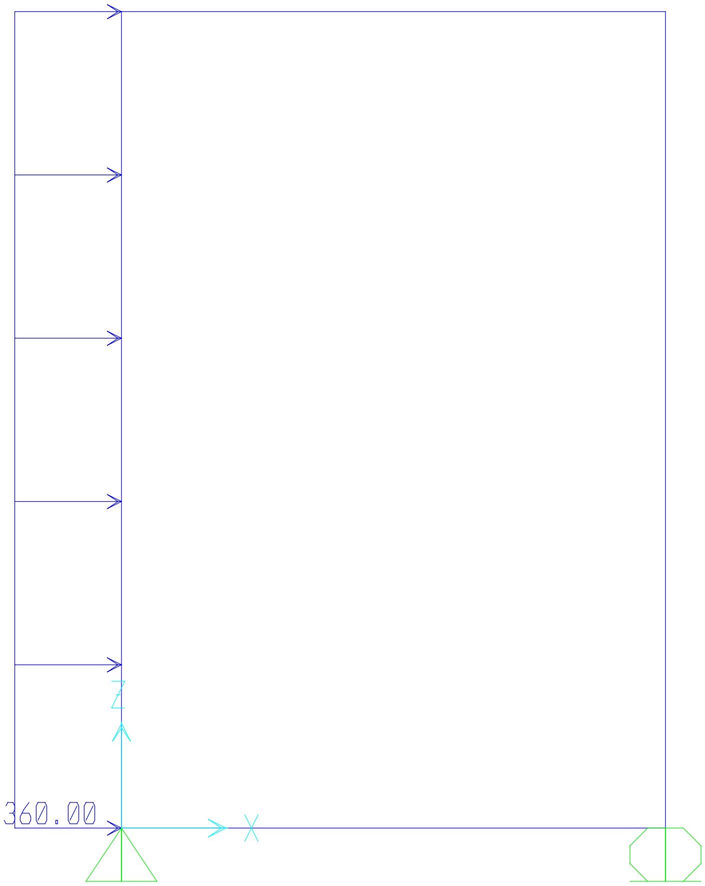
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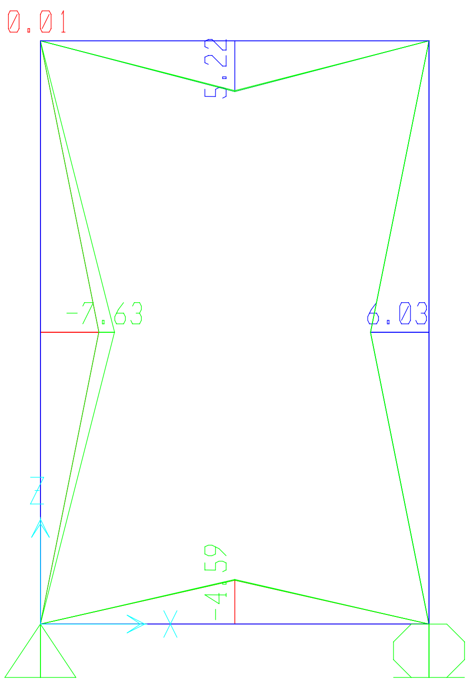

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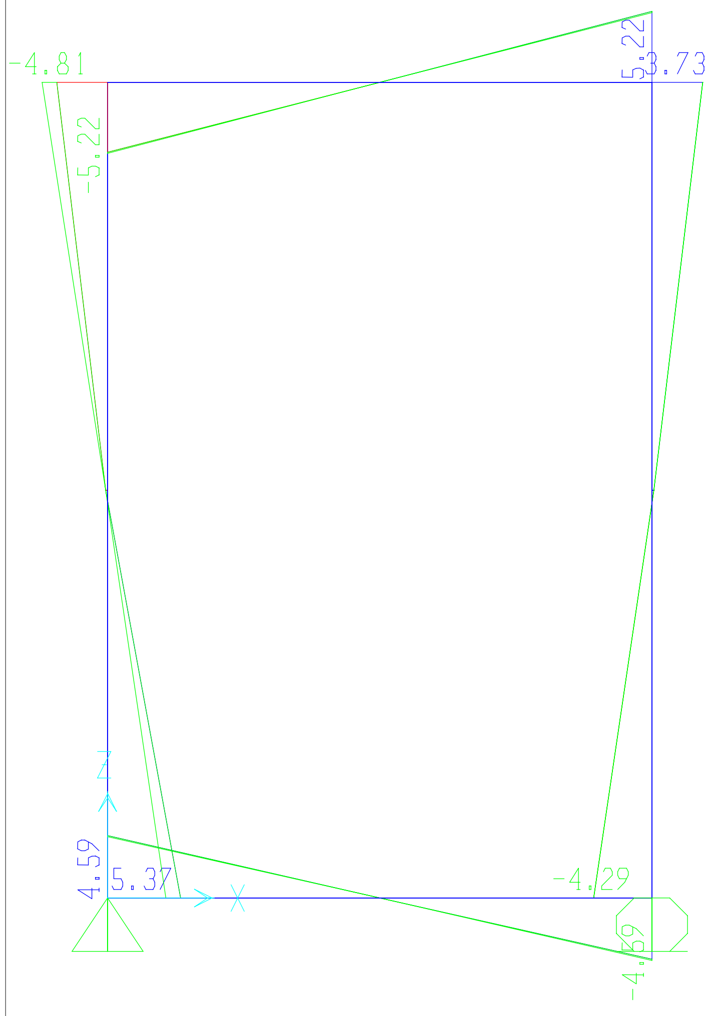
SAP2000 v15.0.0 - File:New box4x6 1_Pin - Moment 3-3 Diagram (ENV) - Kip, ft, F Units



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SAP2000 v15.0.0 - File:New box4x6 1_Pin - Shear Force 2-2 Diagram (ENV) - Kip, ft, F Units

APPENDIX

1. (E) TUNNEL SAP 2000 OUTPUT FILE

2. (N) TUNNEL SAP 2000 OUTPUT FILE

License #27CB6

SAP2000 Analysis Report

Prepared by
jcese

Model Name: box4x6_no L.sdb

18 January 2013

1. Model geometry

This section provides model geometry information, including items such as joint coordinates, joint restraints, and element connectivity.

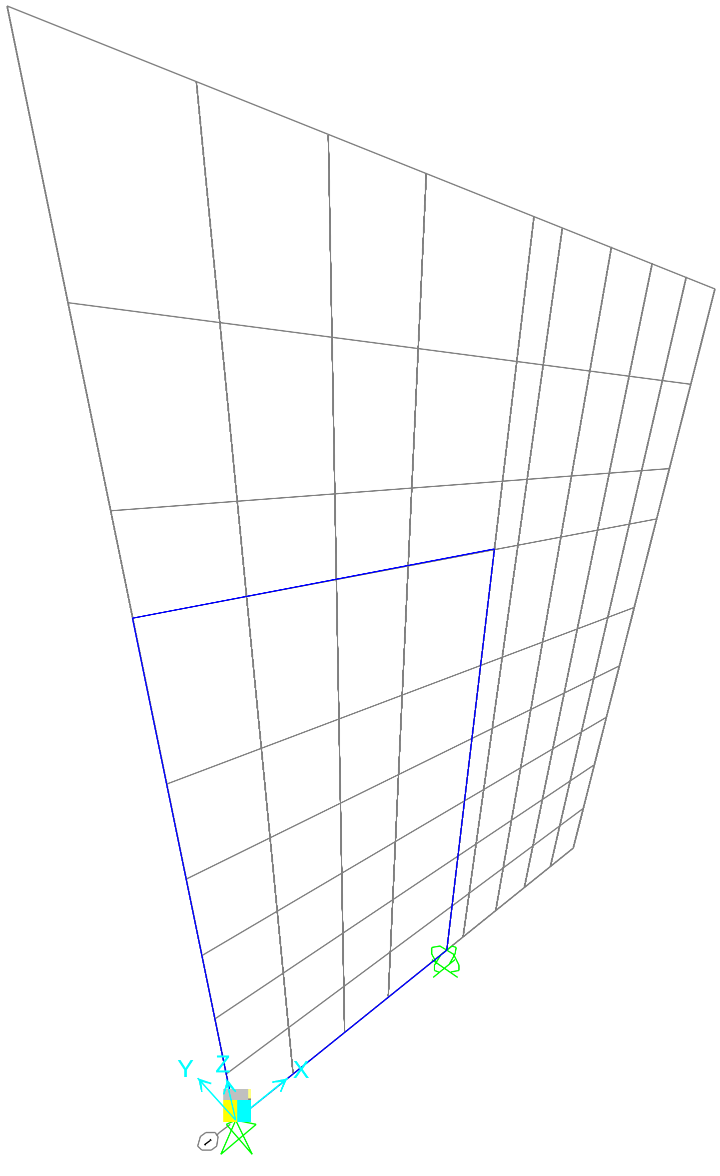


Figure 1: Finite element model

1.1. Joint coordinates

Table 1: Joint Coordinates

Table 1: Joint Coordinates

Joint	CoordSys	CoordType	GlobalX in	GlobalY in	GlobalZ in
1	GLOBAL	Cartesian	0.000	0.000	0.000
2	GLOBAL	Cartesian	0.000	0.000	75.960
3	GLOBAL	Cartesian	54.000	0.000	0.000
4	GLOBAL	Cartesian	54.000	0.000	75.960

1.2. Joint restraints

Table 2: Joint Restraint Assignments

Table 2: Joint Restraint Assignments

Joint	U1	U2	U3	R1	R2	R3
1	Yes	Yes	Yes	No	No	No
3	No	No	Yes	No	No	No

1.3. Element connectivity

Table 3: Connectivity - Frame

Table 3: Connectivity - Frame

Frame	JointI	JointJ	Length in
1	1	2	75.960
2	3	4	75.960
3	1	3	54.000
4	2	4	54.000

Table 4: Frame Section Assignments

Table 4: Frame Section Assignments

Frame	AnalSect	DesignSect	MatProp
1	Rec6dx12	Rec6dx12	Default
2	Rec6dx12	Rec6dx12	Default
3	Rec6dx12	Rec6dx12	Default
4	Rec6dx12	Rec6dx12	Default

2. Material properties

This section provides material property information for materials used in the model.

Table 5: Material Properties 02 - Basic Mechanical Properties

Table 5: Material Properties 02 - Basic Mechanical Properties

Material	UnitWeight	UnitMass	E1	G12	U12	A1
	Kip/in3	Kip-s2/in4	Kip/in2	Kip/in2		1/F
4000Psi	8.6806E-05	2.2483E-07	3604.997	1502.082	0.200000	5.5000E-06
A615Gr60	2.8356E-04	7.3446E-07	29000.000			6.5000E-06

Table 6: Material Properties 03a - Steel Data

Table 6: Material Properties 03a - Steel Data

Material	Fy	Fu	FinalSlope
	Kip/in2	Kip/in2	
A36	36.000	58.000	-0.100000
A992Fy50	50.000	65.000	-0.100000

Table 7: Material Properties 03b - Concrete Data

Table 7: Material Properties 03b - Concrete Data

Material	Fc	FinalSlope
	Kip/in2	
4000Psi	4.000	-0.100000
5000Psi	5.000	-0.100000

Table 8: Material Properties 03e - Rebar Data

Table 8: Material Properties 03e - Rebar Data

Material	Fy	Fu	FinalSlope
	Kip/in2	Kip/in2	
A615Gr60	60.000	90.000	-0.100000

3. Section properties

This section provides section property information for objects used in the model.

3.1. Frames

Table 9: Frame Section Properties 01 - General, Part 1 of 4

Table 9: Frame Section Properties 01 - General, Part 1 of 4

SectionName	Material	Shape	t3	t2	Area	TorsConst	I33	I22
			in	in	in2	in4	in4	in4
Rec6dx12	4000Psi	Rectangular	6.0000	12.0000	72.00	593.26	216.00	864.00

Table 9: Frame Section Properties 01 - General, Part 2 of 4

Table 9: Frame Section Properties 01 - General, Part 2 of 4

SectionName	AS2	AS3
	in2	in2
Rec6dx12	60.00	60.00

Table 9: Frame Section Properties 01 - General, Part 3 of 4

Table 9: Frame Section Properties 01 - General, Part 3 of 4

SectionName	S33	S22	Z33	Z22	R33	R22
	in3	in3	in3	in3	in	in
Rec6dx12	72.00	144.00	108.00	216.00	1.7321	3.4641

Table 9: Frame Section Properties 01 - General, Part 4 of 4

Table 9: Frame Section Properties 01 - General, Part 4 of 4

SectionName	AMod	A2Mod	A3Mod	JMod	I2Mod	I3Mod	MMod	WMod
Rec6dx12	1.000000	1.000000	1.000000	1.000000	0.350000	0.350000	1.000000	1.000000

Table 10: Frame Section Properties 03 - Concrete Beam, Part 1 of 2

Table 10: Frame Section Properties 03 - Concrete Beam, Part 1 of 2

SectionName	RebarMatL	RebarMatC	TopCover	BotCover
			in	in
Rec6dx12	A615Gr60	A615Gr60	1.0000	2.5000

Table 10: Frame Section Properties 03 - Concrete Beam, Part 2 of 2

Table 10: Frame Section Properties 03 - Concrete Beam, Part 2 of 2

SectionName	TopLeftArea	TopRghtArea	BotLeftArea	BotRghtArea
	in2	in2	in2	in2
Rec6dx12	0.0000	0.0000	0.0000	0.0000

4. Load patterns

This section provides loading information as applied to the model.

4.1. Definitions

Table 11: Load Pattern Definitions

Table 11: Load Pattern Definitions

LoadPat	DesignType	SelfWtMult	AutoLoad
DEAD	DEAD	1.000000	
H	LIVE	0.000000	
EQ	QUAKE	0.000000	None

5. Load cases

This section provides load case information.

5.1. Definitions

Table 12: Load Case Definitions

Table 12: Load Case Definitions

Case	Type	InitialCond	ModalCase	BaseCase	DesActOpt	DesignAct
DEAD	LinStatic	Zero			Prog Det	Non-Composite
MODAL	LinModal	Zero			Prog Det	Other
L	LinStatic	Zero			Prog Det	Other
H	LinStatic	Zero			Prog Det	Short-Term Composite
EQ	LinStatic	Zero			Prog Det	Short-Term Composite

5.2. Static case load assignments

Table 13: Case - Static 1 - Load Assignments

Table 13: Case - Static 1 - Load Assignments

Case	LoadType	LoadName	LoadSF
DEAD	Load pattern	DEAD	1.000000
H	Load pattern	H	1.000000
EQ	Load pattern	EQ	1.000000

5.3. Response spectrum case load assignments

Table 14: Function - Response Spectrum - User

Table 14: Function - Response Spectrum - User

Name	Period Sec	Accel	FuncDamp
UNIFRS	0.000000	1.000000	0.050000
UNIFRS	1.000000	1.000000	

6. Load combinations

This section provides load combination information.

Table 15: Combination Definitions

Table 15: Combination Definitions

ComboName	ComboType	CaseName	ScaleFactor
1.2D1.6L	Linear Add	DEAD	1.200000
1.2D1.6L		L	1.600000
1.2D1.6L		H	1.600000
DLH	Linear Add	DEAD	1.000000
DLH		L	1.000000
DLH		H	1.000000
1.2D1L16H1E	Linear Add	DEAD	1.200000
1.2D1L16H1E		L	1.000000
1.2D1L16H1E		H	1.600000
1.2D1L16H1E		EQ	1.000000
0.9D+1.6H+E	Linear Add	DEAD	0.900000
0.9D+1.6H+E		H	1.600000
0.9D+1.6H+E		EQ	1.000000
ENV	Envelope	1.2D1.6L	1.000000
ENV		1.2D1L16H1E	1.000000
ENV		0.9D+1.6H+E	1.000000
DCON1	Linear Add	DEAD	1.400000
DCON2	Linear Add	DEAD	1.200000
DCON2		H	1.600000
DCON3	Linear Add	DEAD	1.200000
DCON3		H	1.000000
DCON3		EQ	1.000000
DCON4	Linear Add	DEAD	1.200000
DCON4		H	1.000000
DCON4		EQ	-1.000000
DCON5	Linear Add	DEAD	0.900000
DCON5		EQ	1.000000
DCON6	Linear Add	DEAD	0.900000
DCON6		EQ	-1.000000

7. Structure results

This section provides structure results, including items such as structural periods and base reactions.

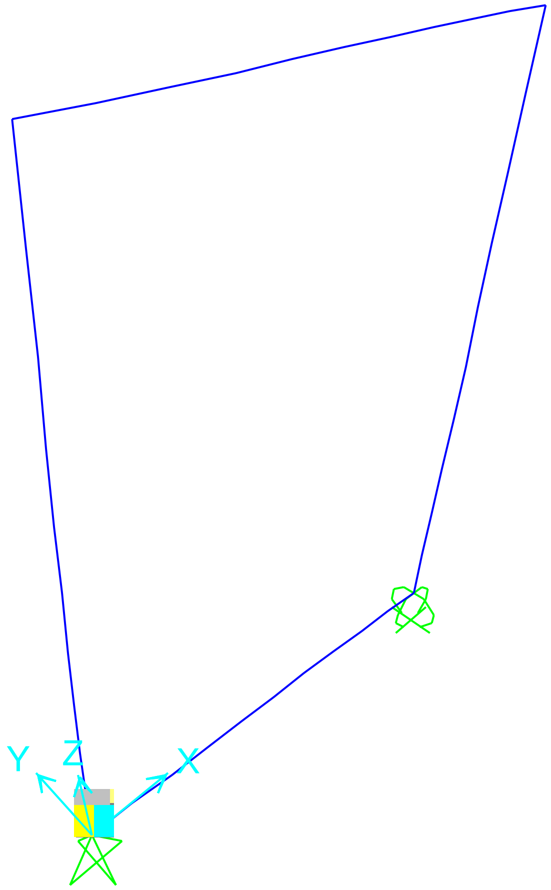


Figure 2: Deformed shape

7.1. Mass summary

Table 16: Assembled Joint Masses

Table 16: Assembled Joint Masses

Joint	U1	U2	U3	R1	R2	R3
	Kip-s2/in	Kip-s2/in	Kip-s2/in	Kip-in-s2	Kip-in-s2	Kip-in-s2
1	0.0011	0.0011	0.0011	0.000	0.000	0.000
2	0.0011	0.0011	0.0011	0.000	0.000	0.000
3	0.0011	0.0011	0.0011	0.000	0.000	0.000
4	0.0011	0.0011	0.0011	0.000	0.000	0.000

7.2. Modal results

Table 17: Modal Participating Mass Ratios

Table 17: Modal Participating Mass Ratios

OutputCase	StepNum	Period	UX	UY	UZ	SumUX	SumUY	SumUZ
		Sec						
MODAL	1.000000	-8691523.4	0.0021	0.8473	6.561E-07	0.0021	0.8473	6.561E-07

7.3. Base reactions

Table: Base Reactions, Part 1 of 3

Table: Base Reactions, Part 1 of 3

OutputCase	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ
			Kip	Kip	Kip	Kip-in	Kip-in	Kip-in
1.2D1.6L	Combination		0.000	0.000	1.973	0.000	-53.282	0.000
DLH	Combination		0.000	0.000	1.645	0.000	-44.401	0.000
1.2D1L16H1E	Combination		-2.279	0.000	1.973	0.000	-139.831	0.000
0.9D+1.6H+E	Combination		-2.279	0.000	1.480	0.000	-126.510	0.000
ENV	Combination	Max	0.000	0.000	1.973	0.000	-53.282	0.000
ENV	Combination	Min	-2.279	0.000	1.480	0.000	-139.831	0.000

Table: Base Reactions, Part 2 of 3

Table: Base Reactions, Part 2 of 3

OutputCase	StepType	GlobalX	GlobalY	GlobalZ	XCentroidFX	YCentroidFX	ZCentroidFX	XCentroidFY
		in	in	in	in	in	in	in
1.2D1.6L		0.000	0.000	0.000	0.000	0.000	0.000	0.000
DLH		0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.2D1L16H1E		0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.9D+1.6H+E		0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENV	Max	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENV	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table: Base Reactions, Part 3 of 3

Table: Base Reactions, Part 3 of 3

OutputCase	StepType	YCentroidFY	ZCentroidFY	XCentroidFZ	YCentroidFZ	ZCentroidFZ
		in	in	in	in	in
1.2D1.6L		0.000	0.000	27.000	0.000	0.000
DLH		0.000	0.000	27.000	0.000	0.000
1.2D1L16H1E		0.000	0.000	70.858	0.000	0.000

Table: Base Reactions, Part 3 of 3

OutputCase	StepType	YCentroidFY	ZCentroidFY	XCentroidFZ	YCentroidFZ	ZCentroidFZ
		in	in	in	in	in
0.9D+1.6H+E		0.000	0.000	85.477	0.000	0.000
ENV	Max	0.000	0.000	0.000	0.000	0.000
ENV	Min	0.000	0.000	0.000	0.000	0.000

8. Joint results

This section provides joint results, including items such as displacements and reactions.

Table: Joint Reactions, Part 1 of 2

Table: Joint Reactions, Part 1 of 2

Joint	OutputCase	CaseType	StepType	F1	F2	F3	M1	M2
				Kip	Kip	Kip	Kip-in	Kip-in
1	1.2D1.6L	Combination		-1.041E-18	0.000	0.987	0.000	0.000
1	DLH	Combination		-8.674E-19	0.000	0.822	0.000	0.000
1	1.2D1L16H1E	Combination		-2.279	0.000	-0.616	0.000	0.000
1	0.9D+1.6H+E	Combination		-2.279	0.000	-0.863	0.000	0.000
1	ENV	Combination	Max	-1.041E-18	0.000	0.987	0.000	0.000
1	ENV	Combination	Min	-2.279	0.000	-0.863	0.000	0.000
3	1.2D1.6L	Combination		0.000	0.000	0.987	0.000	0.000
3	DLH	Combination		0.000	0.000	0.822	0.000	0.000
3	1.2D1L16H1E	Combination		0.000	0.000	2.589	0.000	0.000
3	0.9D+1.6H+E	Combination		0.000	0.000	2.343	0.000	0.000
3	ENV	Combination	Max	0.000	0.000	2.589	0.000	0.000
3	ENV	Combination	Min	0.000	0.000	0.987	0.000	0.000

Table: Joint Reactions, Part 2 of 2

Table: Joint Reactions, Part 2 of 2

Joint	OutputCase	StepType	M3
			Kip-in
1	1.2D1.6L		0.000
1	DLH		0.000
1	1.2D1L16H1E		0.000
1	0.9D+1.6H+E		0.000
1	ENV	Max	0.000
1	ENV	Min	0.000
3	1.2D1.6L		0.000
3	DLH		0.000
3	1.2D1L16H1E		0.000
3	0.9D+1.6H+E		0.000
3	ENV	Max	0.000
3	ENV	Min	0.000

9. Frame results

This section provides frame force results.

See Graphical Outputs.

10. Material take-off

This section provides a material take-off.

Table 18: Material List 2 - By Section Property

Table 18: Material List 2 - By Section Property

Section	ObjectType	NumPieces	TotalLength	TotalWeight
			in	Kip
Rec6dx12	Frame	4	259.920	1.625

License #27CB6

SAP2000 Analysis Report

Prepared by
jcese

Model Name: New box4x6 1_Pin.sdb

18 January 2013

1. Model geometry

This section provides model geometry information, including items such as joint coordinates, joint restraints, and element connectivity.

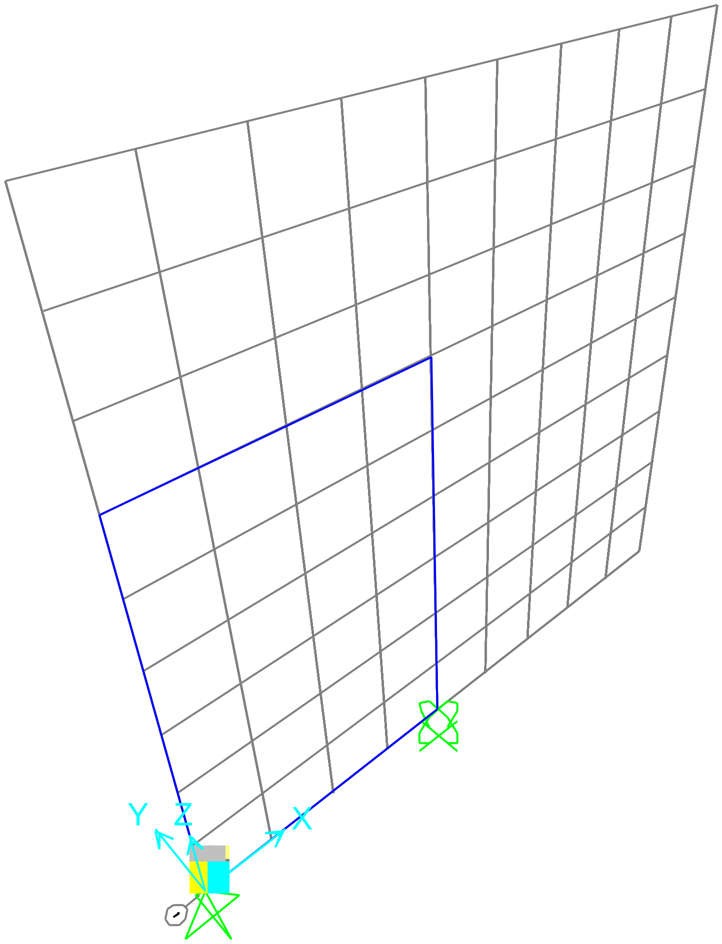


Figure 1: Finite element model

1.1. Joint coordinates

Table 1: Joint Coordinates

Table 1: Joint Coordinates

Joint	CoordSys	CoordType	GlobalX ft	GlobalY ft	GlobalZ ft
1	GLOBAL	Cartesian	0.0000	0.0000	0.0000
2	GLOBAL	Cartesian	0.0000	0.0000	6.0000
3	GLOBAL	Cartesian	4.0000	0.0000	0.0000
4	GLOBAL	Cartesian	4.0000	0.0000	6.0000

1.2. *Joint restraints*

Table 2: Joint Restraint Assignments

Table 2: Joint Restraint Assignments

Joint	U1	U2	U3	R1	R2	R3
1	Yes	Yes	Yes	No	No	No
3	No	No	Yes	No	No	No

1.3. *Element connectivity*

Table 3: Connectivity - Frame

Table 3: Connectivity - Frame

Frame	JointI	JointJ	Length ft
1	1	2	6.0000
2	3	4	6.0000
3	1	3	4.0000
4	2	4	4.0000

Table 4: Frame Section Assignments

Table 4: Frame Section Assignments

Frame	AnalSect	DesignSect	MatProp
1	Rec12dx12	Rec12dx12	Default
2	Rec12dx12	Rec12dx12	Default
3	Rec12dx12	Rec12dx12	Default
4	Rec12dx12	Rec12dx12	Default

Table 5: Frame Release Assignments 1 - General, Part 1 of 2

Table 5: Frame Release Assignments 1 - General, Part 1 of 2

Frame	PI	V2I	V3I	TI	M2I	M3I
3	No	No	No	Yes	Yes	Yes
4	No	No	No	Yes	Yes	Yes

Table 5: Frame Release Assignments 1 - General, Part 2 of 2

Table 5: Frame Release Assignments 1 - General, Part 2 of 2

Frame	PJ	V2J	V3J	TJ	M2J	M3J
3	No	No	No	No	Yes	Yes
4	No	No	No	No	Yes	Yes

2. Material properties

This section provides material property information for materials used in the model.

Table 6: Material Properties 02 - Basic Mechanical Properties

Table 6: Material Properties 02 - Basic Mechanical Properties

Material	UnitWeight	UnitMass	E1	G12	U12	A1
	Kip/ft3	Kip-s2/ft4	Kip/ft2	Kip/ft2		1/F
4000Psi	1.5000E-01	4.6621E-03	519119.50	216299.79	0.200000	5.5000E-06
5000Psi	1.5000E-01	4.6621E-03	580393.25	241830.52	0.200000	5.5000E-06
A36	4.9000E-01	1.5230E-02	4176000.00	1606153.85	0.300000	6.5000E-06
A615Gr60	4.9000E-01	1.5230E-02	4176000.00			6.5000E-06
A992Fy50	4.9000E-01	1.5230E-02	4176000.00	1606153.85	0.300000	6.5000E-06

Table 7: Material Properties 03a - Steel Data

Table 7: Material Properties 03a - Steel Data

Material	Fy	Fu	FinalSlope
	Kip/ft2	Kip/ft2	
A36	5184.00	8352.00	-0.100000
A992Fy50	7200.00	9360.00	-0.100000

Table 8: Material Properties 03b - Concrete Data

Table 8: Material Properties 03b - Concrete Data

Material	Fc	FinalSlope
	Kip/ft2	
4000Psi	576.00	-0.100000
5000Psi	720.00	-0.100000

Table 9: Material Properties 03e - Rebar Data

Table 9: Material Properties 03e - Rebar Data

Material	Fy	Fu	FinalSlope
	Kip/ft2	Kip/ft2	
A615Gr60	8640.00	12960.00	-0.100000

3. Section properties

This section provides section property information for objects used in the model.

3.1. Frames

Table 10: Frame Section Properties 01 - General, Part 1 of 4

Table 10: Frame Section Properties 01 - General, Part 1 of 4

SectionName	Material	Shape	t3 ft	t2 ft	Area ft2	TorsConst ft4	I33 ft4	I22 ft4
Rec12dx12	4000Psi	Rectangular	1.00000	1.00000	1.0000	0.140833	0.083333	0.083333
Rec6dx12	4000Psi	Rectangular	0.50000	1.00000	0.5000	0.028610	0.010417	0.041667

Table 10: Frame Section Properties 01 - General, Part 2 of 4

Table 10: Frame Section Properties 01 - General, Part 2 of 4

SectionName	AS2 ft2	AS3 ft2
Rec12dx12	0.8333	0.8333
Rec6dx12	0.4167	0.4167

Table 10: Frame Section Properties 01 - General, Part 3 of 4

Table 10: Frame Section Properties 01 - General, Part 3 of 4

SectionName	S33 ft3	S22 ft3	Z33 ft3	Z22 ft3	R33 ft	R22 ft
Rec12dx12	0.166667	0.166667	0.250000	0.250000	0.28868	0.28868
Rec6dx12	0.041667	0.083333	0.062500	0.125000	0.14434	0.28868

Table 10: Frame Section Properties 01 - General, Part 4 of 4

Table 10: Frame Section Properties 01 - General, Part 4 of 4

SectionName	AMod	A2Mod	A3Mod	JMod	I2Mod	I3Mod	MMod	WMod
Rec12dx12	1.000000	1.000000	1.000000	1.000000	0.350000	0.350000	1.000000	1.000000
Rec6dx12	1.000000	1.000000	1.000000	1.000000	0.350000	0.350000	1.000000	1.000000

Table 11: Frame Section Properties 03 - Concrete Beam, Part 1 of 2

Table 11: Frame Section Properties 03 - Concrete Beam, Part 1 of 2

SectionName	RebarMatL	RebarMatC	TopCover ft	BotCover ft
Rec12dx12	A615Gr60	A615Gr60	0.20833	0.20833
Rec6dx12	A615Gr60	A615Gr60	0.08333	0.20833

Table 11: Frame Section Properties 03 - Concrete Beam, Part 2 of 2

Table 11: Frame Section Properties 03 - Concrete Beam, Part 2 of 2

SectionName	TopLeftArea	TopRghtArea	BotLeftArea	BotRghtArea
	ft2	ft2	ft2	ft2
Rec12dx12	0.000000	0.000000	0.000000	0.000000
Rec6dx12	0.000000	0.000000	0.000000	0.000000

4. Load patterns

This section provides loading information as applied to the model.

4.1. Definitions

Table 12: Load Pattern Definitions

Table 12: Load Pattern Definitions

LoadPat	DesignType	SelfWtMult	AutoLoad
DEAD	DEAD	1.000000	
H	LIVE	0.000000	
EQ	QUAKE	0.000000	None

5. Load cases

This section provides load case information.

5.1. Definitions

Table 13: Load Case Definitions

Table 13: Load Case Definitions

Case	Type	InitialCond	ModalCase	BaseCase	DesActOpt	DesignAct
DEAD	LinStatic	Zero			Prog Det	Non-Composite
MODAL	LinModal	Zero			Prog Det	Other
L	LinStatic	Zero			Prog Det	Other
H	LinStatic	Zero			Prog Det	Short-Term Composite
EQ	LinStatic	Zero			Prog Det	Short-Term Composite

5.2. Static case load assignments

Table 14: Case - Static 1 - Load Assignments

Table 14: Case - Static 1 - Load Assignments

Case	LoadType	LoadName	LoadSF
DEAD	Load pattern	DEAD	1.000000
H	Load pattern	H	1.000000
EQ	Load pattern	EQ	1.000000

5.3. Response spectrum case load assignments

Table 15: Function - Response Spectrum - User

Table 15: Function - Response Spectrum - User

Name	Period	Accel	FuncDamp
	Sec		
UNIFRS	0.000000	1.000000	0.050000
UNIFRS	1.000000	1.000000	

6. Load combinations

This section provides load combination information.

Table 16: Combination Definitions

Table 16: Combination Definitions

ComboName	ComboType	CaseName	ScaleFactor
1.2D1.6L	Linear Add	DEAD	1.200000
1.2D1.6L		L	1.600000
1.2D1.6L		H	1.600000
DLH	Linear Add	DEAD	1.000000
DLH		L	1.000000
DLH		H	1.000000
1.2D1L16H1E	Linear Add	DEAD	1.200000
1.2D1L16H1E		L	1.000000
1.2D1L16H1E		H	1.600000
1.2D1L16H1E		EQ	1.000000
0.9D+1.6H+E	Linear Add	DEAD	0.900000
0.9D+1.6H+E		H	1.600000
0.9D+1.6H+E		EQ	1.000000
ENV	Envelope	1.2D1.6L	1.000000
ENV		1.2D1L16H1E	1.000000
ENV		0.9D+1.6H+E	1.000000
DCON1	Linear Add	DEAD	1.400000
DCON2	Linear Add	DEAD	1.200000
DCON2		H	1.600000
DCON3	Linear Add	DEAD	1.200000
DCON3		H	1.000000
DCON3		EQ	1.000000
DCON4	Linear Add	DEAD	1.200000
DCON4		H	1.000000

Table 16: Combination Definitions

ComboName	ComboType	CaseName	ScaleFactor
DCON4		EQ	-1.000000
DCON5	Linear Add	DEAD	0.900000
DCON5		EQ	1.000000
DCON6	Linear Add	DEAD	0.900000
DCON6		EQ	-1.000000

7. Structure results

This section provides structure results, including items such as structural periods and base reactions.

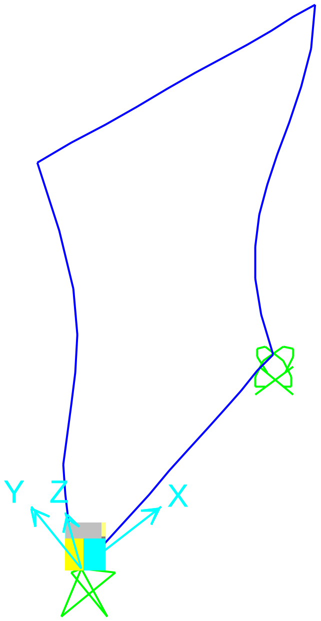


Figure 2: Deformed shape

7.1. *Mass summary*

Table 17: Assembled Joint Masses

Table 17: Assembled Joint Masses

Joint	U1 Kip-s2/ft	U2 Kip-s2/ft	U3 Kip-s2/ft	R1 Kip-ft-s2	R2 Kip-ft-s2	R3 Kip-ft-s2
1	2.331E-02	2.331E-02	2.331E-02	0.0000	0.0000	0.0000
2	2.331E-02	2.331E-02	2.331E-02	0.0000	0.0000	0.0000
3	2.331E-02	2.331E-02	2.331E-02	0.0000	0.0000	0.0000
4	2.331E-02	2.331E-02	2.331E-02	0.0000	0.0000	0.0000

7.2. *Modal results*

Table 18: Modal Participating Mass Ratios

Table 18: Modal Participating Mass Ratios

OutputCase	StepNum	Period Sec	UX	UY	UZ	SumUX	SumUY	SumUZ
MODAL	1.000000	15371521. 05	0.27319	0.35337	4.701E-05	0.27319	0.35337	4.701E-05

7.3. Base reactions

Table 19: Base Reactions

Table 19: Base Reactions

OutputCase	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ
		Kip	Kip	Kip	Kip-ft	Kip-ft	Kip-ft
DEAD		-5.568E-08	0.000	3.020	0.0000	-6.0400	0.0000
L		0.000	0.000	0.000	0.0000	0.0000	0.0000
H		4.441E-16	0.000	0.000	0.0000	0.0000	0.0000
EQ		-1.080	0.000	0.000	0.0000	0.0000	0.0000

8. Joint results

This section provides joint results, including items such as displacements and reactions.

Table 20: Joint Displacements

Table 20: Joint Displacements

Joint	OutputCase	StepType	U1	U2	U3	R1	R2	R3
			ft	ft	ft	Radians	Radians	Radians
1	DEAD		0.000000	0.000000	0.000000	0.000000	-240.567034	0.000000
1	L		0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1	H		0.000000	0.000000	0.000000	0.000000	0.000507	0.000000
1	EQ		0.000000	0.000000	0.000000	0.000000	4676623136	0.000000
2	DEAD		-1443.40220	0.000000	-8.784E-06	0.000000	-240.567034	0.000000
2	L		0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	H		0.000022	0.000000	-0.000035	0.000000	-0.000486	0.000000
2	EQ		2.806E+10	0.000000	0.000000	0.000000	4676623136	0.000000
3	DEAD		8.562E-09	0.000000	0.000000	0.000000	-240.567034	0.000000
3	L		0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	H		-0.000021	0.000000	0.000000	0.000000	-0.000499	0.000000
3	EQ		1.490E-08	0.000000	0.000000	0.000000	4676623136	0.000000
4	DEAD		-1443.40220	0.000000	-8.784E-06	0.000000	-240.567034	0.000000
4	L		0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	H		4.340E-06	0.000000	-0.000035	0.000000	0.000494	0.000000
4	EQ		2.806E+10	0.000000	0.000000	0.000000	4676623136	0.000000

Table 21: Joint Reactions

Table 21: Joint Reactions

Joint	OutputCase	StepType	F1	F2	F3	M1	M2	M3
			Kip	Kip	Kip	Kip-ft	Kip-ft	Kip-ft
1	DEAD		-5.568E-08	0.000	1.510	0.0000	0.0000	0.0000
1	L		0.000	0.000	0.000	0.0000	0.0000	0.0000
1	H		4.441E-16	0.000	0.000	0.0000	0.0000	0.0000
1	EQ		-1.080	0.000	0.000	0.0000	0.0000	0.0000
3	DEAD		0.000	0.000	1.510	0.0000	0.0000	0.0000

Table 21: Joint Reactions

Joint	OutputCase	StepType	F1 Kip	F2 Kip	F3 Kip	M1 Kip-ft	M2 Kip-ft	M3 Kip-ft
3	L		0.000	0.000	0.000	0.0000	0.0000	0.0000
3	H		0.000	0.000	0.000	0.0000	0.0000	0.0000
3	EQ		0.000	0.000	0.000	0.0000	0.0000	0.0000

9. Frame results

This section provides frame force results.

Table 22: Element Forces - Frames, Part 1 of 4

Table 22: Element Forces - Frames, Part 1 of 4

Frame	Station ft	OutputCase	StepType	P Kip	V2 Kip	V3 Kip
1	0.0000	DEAD		-1.210	-1.111E-03	0.000
1	3.0000	DEAD		-0.760	-1.111E-03	0.000
1	3.0000	DEAD		-0.760	-1.111E-03	0.000
1	6.0000	DEAD		-0.310	-1.111E-03	0.000
1	0.0000	L		0.000	0.000	0.000
1	3.0000	L		0.000	0.000	0.000
1	3.0000	L		0.000	0.000	0.000
1	6.0000	L		0.000	0.000	0.000
1	0.0000	H		-3.040	2.680	0.000
1	3.0000	H		-3.040	-0.087	0.000
1	3.0000	H		-3.040	-0.087	0.000
1	6.0000	H		-3.040	-2.330	0.000
1	0.0000	EQ		0.000	1.078	0.000
1	3.0000	EQ		0.000	-1.875E-03	0.000
1	3.0000	EQ		0.000	-1.875E-03	0.000
1	6.0000	EQ		0.000	-1.082	0.000
2	0.0000	DEAD		-1.210	1.111E-03	0.000
2	3.0000	DEAD		-0.760	1.111E-03	0.000
2	3.0000	DEAD		-0.760	1.111E-03	0.000
2	6.0000	DEAD		-0.310	1.111E-03	0.000
2	0.0000	L		0.000	0.000	0.000
2	3.0000	L		0.000	0.000	0.000
2	3.0000	L		0.000	0.000	0.000
2	6.0000	L		0.000	0.000	0.000
2	0.0000	H		-3.040	-2.680	0.000
2	3.0000	H		-3.040	0.087	0.000
2	3.0000	H		-3.040	0.087	0.000
2	6.0000	H		-3.040	2.330	0.000
2	0.0000	EQ		0.000	1.953E-03	0.000
2	3.0000	EQ		0.000	1.953E-03	0.000
2	3.0000	EQ		0.000	1.953E-03	0.000
2	6.0000	EQ		0.000	1.953E-03	0.000
3	0.0000	DEAD		1.111E-03	-0.300	0.000
3	2.0000	DEAD		1.111E-03	1.110E-16	0.000
3	4.0000	DEAD		1.111E-03	0.300	0.000
3	0.0000	L		0.000	0.000	0.000
3	2.0000	L		0.000	0.000	0.000
3	4.0000	L		0.000	0.000	0.000

Table 22: Element Forces - Frames, Part 1 of 4

Frame	Station	OutputCase	StepType	P	V2	V3
	ft			Kip	Kip	Kip
3	0.0000	H		-2.680	3.040	0.000
3	2.0000	H		-2.680	0.000	0.000
3	4.0000	H		-2.680	-3.040	0.000
3	0.0000	EQ		1.934E-03	0.000	0.000
3	2.0000	EQ		1.934E-03	0.000	0.000
3	4.0000	EQ		1.934E-03	0.000	0.000
4	0.0000	DEAD		-1.111E-03	-0.300	0.000
4	2.0000	DEAD		-1.111E-03	1.110E-16	0.000
4	4.0000	DEAD		-1.111E-03	0.300	0.000
4	0.0000	L		0.000	0.000	0.000
4	2.0000	L		0.000	0.000	0.000
4	4.0000	L		0.000	0.000	0.000
4	0.0000	H		-2.330	-3.040	0.000
4	2.0000	H		-2.330	0.000	0.000
4	4.0000	H		-2.330	3.040	0.000
4	0.0000	EQ		-1.000	0.000	0.000
4	2.0000	EQ		-1.000	0.000	0.000
4	4.0000	EQ		-1.000	0.000	0.000

Table 22: Element Forces - Frames, Part 2 of 4

Table 22: Element Forces - Frames, Part 2 of 4

Frame	Station	OutputCase	StepType	T	M2	M3	S11Max	PtS11Max
	ft			Kip-ft	Kip-ft	Kip-ft	Kip/ft2	
1	0.0000	DEAD		0.0000	0.0000	-9.313E-10	-1.21	3
1	3.0000	DEAD		0.0000	0.0000	0.0033	-0.74	1
1	3.0000	DEAD		0.0000	0.0000	-0.0033	-0.74	3
1	6.0000	DEAD		0.0000	0.0000	-7.140E-11	-0.31	3
1	0.0000	L		0.0000	0.0000	0.0000	0.00	0
1	3.0000	L		0.0000	0.0000	0.0000	0.00	0
1	3.0000	L		0.0000	0.0000	0.0000	0.00	0
1	6.0000	L		0.0000	0.0000	0.0000	0.00	0
1	0.0000	H		0.0000	0.0000	0.0000	-3.04	0
1	3.0000	H		0.0000	0.0000	-3.7575	19.51	3
1	3.0000	H		0.0000	0.0000	-3.7575	19.51	3
1	6.0000	H		0.0000	0.0000	-4.441E-15	-3.04	3
1	0.0000	EQ		0.0000	0.0000	0.0000	0.00	0
1	3.0000	EQ		0.0000	0.0000	-1.6144	9.69	3
1	3.0000	EQ		0.0000	0.0000	-1.6144	9.69	3
1	6.0000	EQ		0.0000	0.0000	0.0113	6.750E-02	1
2	0.0000	DEAD		0.0000	0.0000	0.0000	-1.21	0
2	3.0000	DEAD		0.0000	0.0000	-0.0033	-0.74	3
2	3.0000	DEAD		0.0000	0.0000	0.0033	-0.74	1
2	6.0000	DEAD		0.0000	0.0000	-1.406E-09	-0.31	3
2	0.0000	L		0.0000	0.0000	0.0000	0.00	0
2	3.0000	L		0.0000	0.0000	0.0000	0.00	0
2	3.0000	L		0.0000	0.0000	0.0000	0.00	0
2	6.0000	L		0.0000	0.0000	0.0000	0.00	0
2	0.0000	H		0.0000	0.0000	-4.441E-16	-3.04	3
2	3.0000	H		0.0000	0.0000	3.7575	19.51	1
2	3.0000	H		0.0000	0.0000	3.7575	19.51	1
2	6.0000	H		0.0000	0.0000	4.441E-15	-3.04	1
2	0.0000	EQ		0.0000	0.0000	0.0156	9.375E-02	1

Table 22: Element Forces - Frames, Part 2 of 4

Frame	Station	OutputCase	StepType	T	M2	M3	S11Max	PtS11Max
	ft			Kip-ft	Kip-ft	Kip-ft	Kip/ft2	
2	3.0000	EQ		0.0000	0.0000	0.0098	5.859E-02	1
2	3.0000	EQ		0.0000	0.0000	0.0098	5.859E-02	1
2	6.0000	EQ		0.0000	0.0000	0.0039	2.344E-02	1
3	0.0000	DEAD		0.0000	0.0000	0.0000	1.111E-03	0
3	2.0000	DEAD		0.0000	0.0000	0.3000	1.80	1
3	4.0000	DEAD		0.0000	0.0000	-4.441E-16	1.111E-03	3
3	0.0000	L		0.0000	0.0000	0.0000	0.00	0
3	2.0000	L		0.0000	0.0000	0.0000	0.00	0
3	4.0000	L		0.0000	0.0000	0.0000	0.00	0
3	0.0000	H		0.0000	0.0000	0.0000	-2.68	0
3	2.0000	H		0.0000	0.0000	-3.0400	15.56	3
3	4.0000	H		0.0000	0.0000	0.0000	-2.68	0
3	0.0000	EQ		0.0000	0.0000	0.0000	1.934E-03	0
3	2.0000	EQ		0.0000	0.0000	0.0000	1.934E-03	0
3	4.0000	EQ		0.0000	0.0000	0.0000	1.934E-03	0
4	0.0000	DEAD		0.0000	0.0000	0.0000	-1.111E-03	0
4	2.0000	DEAD		0.0000	0.0000	0.3000	1.80	1
4	4.0000	DEAD		0.0000	0.0000	-4.441E-16	-1.111E-03	3
4	0.0000	L		0.0000	0.0000	0.0000	0.00	0
4	2.0000	L		0.0000	0.0000	0.0000	0.00	0
4	4.0000	L		0.0000	0.0000	0.0000	0.00	0
4	0.0000	H		0.0000	0.0000	0.0000	-2.33	0
4	2.0000	H		0.0000	0.0000	3.0400	15.91	1
4	4.0000	H		0.0000	0.0000	0.0000	-2.33	0
4	0.0000	EQ		0.0000	0.0000	0.0000	-1.00	0
4	2.0000	EQ		0.0000	0.0000	0.0000	-1.00	0
4	4.0000	EQ		0.0000	0.0000	0.0000	-1.00	0

Table 22: Element Forces - Frames, Part 3 of 4

Table 22: Element Forces - Frames, Part 3 of 4

Frame	Station	OutputCase	StepType	x2S11Max	x3S11Max	S11Min	PtS11Min	x2S11Min
	ft			ft	ft	Kip/ft2		ft
1	0.0000	DEAD		0.50000	-0.50000	-1.21	1	-0.50000
1	3.0000	DEAD		-0.50000	-0.50000	-0.78	3	0.50000
1	3.0000	DEAD		0.50000	-0.50000	-0.78	1	-0.50000
1	6.0000	DEAD		0.50000	-0.50000	-0.31	1	-0.50000
1	0.0000	L		0.00000	0.00000	0.00	0	0.00000
1	3.0000	L		0.00000	0.00000	0.00	0	0.00000
1	3.0000	L		0.00000	0.00000	0.00	0	0.00000
1	6.0000	L		0.00000	0.00000	0.00	0	0.00000
1	0.0000	H		0.00000	0.00000	-3.04	0	0.00000
1	3.0000	H		0.50000	-0.50000	-25.59	1	-0.50000
1	3.0000	H		0.50000	-0.50000	-25.59	1	-0.50000
1	6.0000	H		0.50000	-0.50000	-3.04	1	-0.50000
1	0.0000	EQ		0.00000	0.00000	0.00	0	0.00000
1	3.0000	EQ		0.50000	-0.50000	-9.69	1	-0.50000
1	3.0000	EQ		0.50000	-0.50000	-9.69	1	-0.50000
1	6.0000	EQ		-0.50000	-0.50000	-6.750E-02	3	0.50000
2	0.0000	DEAD		0.00000	0.00000	-1.21	0	0.00000
2	3.0000	DEAD		0.50000	-0.50000	-0.78	1	-0.50000
2	3.0000	DEAD		-0.50000	-0.50000	-0.78	3	0.50000
2	6.0000	DEAD		0.50000	-0.50000	-0.31	1	-0.50000

Table 22: Element Forces - Frames, Part 3 of 4

Frame	Station	OutputCase	StepType	x2S11Max	x3S11Max	S11Min	PtS11Min	x2S11Min
	ft			ft	ft	Kip/ft2		ft
2	0.0000	L		0.00000	0.00000	0.00	0	0.00000
2	3.0000	L		0.00000	0.00000	0.00	0	0.00000
2	3.0000	L		0.00000	0.00000	0.00	0	0.00000
2	6.0000	L		0.00000	0.00000	0.00	0	0.00000
2	0.0000	H		0.50000	-0.50000	-3.04	1	-0.50000
2	3.0000	H		-0.50000	-0.50000	-25.59	3	0.50000
2	3.0000	H		-0.50000	-0.50000	-25.59	3	0.50000
2	6.0000	H		-0.50000	-0.50000	-3.04	3	0.50000
2	0.0000	EQ		-0.50000	-0.50000	-9.375E-02	3	0.50000
2	3.0000	EQ		-0.50000	-0.50000	-5.859E-02	3	0.50000
2	3.0000	EQ		-0.50000	-0.50000	-5.859E-02	3	0.50000
2	6.0000	EQ		-0.50000	-0.50000	-2.344E-02	3	0.50000
3	0.0000	DEAD		0.00000	0.00000	1.111E-03	0	0.00000
3	2.0000	DEAD		-0.50000	-0.50000	-1.80	3	0.50000
3	4.0000	DEAD		0.50000	-0.50000	1.111E-03	1	-0.50000
3	0.0000	L		0.00000	0.00000	0.00	0	0.00000
3	2.0000	L		0.00000	0.00000	0.00	0	0.00000
3	4.0000	L		0.00000	0.00000	0.00	0	0.00000
3	0.0000	H		0.00000	0.00000	-2.68	0	0.00000
3	2.0000	H		0.50000	-0.50000	-20.92	1	-0.50000
3	4.0000	H		0.00000	0.00000	-2.68	0	0.00000
3	0.0000	EQ		0.00000	0.00000	1.934E-03	0	0.00000
3	2.0000	EQ		0.00000	0.00000	1.934E-03	0	0.00000
3	4.0000	EQ		0.00000	0.00000	1.934E-03	0	0.00000
4	0.0000	DEAD		0.00000	0.00000	-1.111E-03	0	0.00000
4	2.0000	DEAD		-0.50000	-0.50000	-1.80	3	0.50000
4	4.0000	DEAD		0.50000	-0.50000	-1.111E-03	1	-0.50000
4	0.0000	L		0.00000	0.00000	0.00	0	0.00000
4	2.0000	L		0.00000	0.00000	0.00	0	0.00000
4	4.0000	L		0.00000	0.00000	0.00	0	0.00000
4	0.0000	H		0.00000	0.00000	-2.33	0	0.00000
4	2.0000	H		-0.50000	-0.50000	-20.57	3	0.50000
4	4.0000	H		0.00000	0.00000	-2.33	0	0.00000
4	0.0000	EQ		0.00000	0.00000	-1.00	0	0.00000
4	2.0000	EQ		0.00000	0.00000	-1.00	0	0.00000
4	4.0000	EQ		0.00000	0.00000	-1.00	0	0.00000

Table 22: Element Forces - Frames, Part 4 of 4

Table 22: Element Forces - Frames, Part 4 of 4

Frame	Station	OutputCase	StepType	x3S11Min
	ft			ft
1	0.0000	DEAD		-0.50000
1	3.0000	DEAD		-0.50000
1	3.0000	DEAD		-0.50000
1	6.0000	DEAD		-0.50000
1	0.0000	L		0.00000
1	3.0000	L		0.00000
1	3.0000	L		0.00000
1	6.0000	L		0.00000
1	0.0000	H		0.00000
1	3.0000	H		-0.50000
1	3.0000	H		-0.50000

Table 22: Element Forces - Frames, Part 4 of 4

Frame	Station ft	OutputCase	StepType	x3S11Min ft
1	6.0000	H		-0.50000
1	0.0000	EQ		0.00000
1	3.0000	EQ		-0.50000
1	3.0000	EQ		-0.50000
1	6.0000	EQ		-0.50000
2	0.0000	DEAD		0.00000
2	3.0000	DEAD		-0.50000
2	3.0000	DEAD		-0.50000
2	6.0000	DEAD		-0.50000
2	0.0000	L		0.00000
2	3.0000	L		0.00000
2	3.0000	L		0.00000
2	6.0000	L		0.00000
2	0.0000	H		-0.50000
2	3.0000	H		-0.50000
2	3.0000	H		-0.50000
2	6.0000	H		-0.50000
2	0.0000	EQ		-0.50000
2	3.0000	EQ		-0.50000
2	3.0000	EQ		-0.50000
2	6.0000	EQ		-0.50000
3	0.0000	DEAD		0.00000
3	2.0000	DEAD		-0.50000
3	4.0000	DEAD		-0.50000
3	0.0000	L		0.00000
3	2.0000	L		0.00000
3	4.0000	L		0.00000
3	0.0000	H		0.00000
3	2.0000	H		-0.50000
3	4.0000	H		0.00000
3	0.0000	EQ		0.00000
3	2.0000	EQ		0.00000
3	4.0000	EQ		0.00000
4	0.0000	DEAD		0.00000
4	2.0000	DEAD		-0.50000
4	4.0000	DEAD		-0.50000
4	0.0000	L		0.00000
4	2.0000	L		0.00000
4	4.0000	L		0.00000
4	0.0000	H		0.00000
4	2.0000	H		-0.50000
4	4.0000	H		0.00000
4	0.0000	EQ		0.00000
4	2.0000	EQ		0.00000
4	4.0000	EQ		0.00000

10. Material take-off

This section provides a material take-off.

Table 23: Material List 2 - By Section Property

Table 23: Material List 2 - By Section Property

Section	ObjectType	NumPieces	TotalLength ft	TotalWeight Kip
Rec12dx12	Frame	4	20.0000	3.000

APPENDIX C

FIGURES & PHOTOS

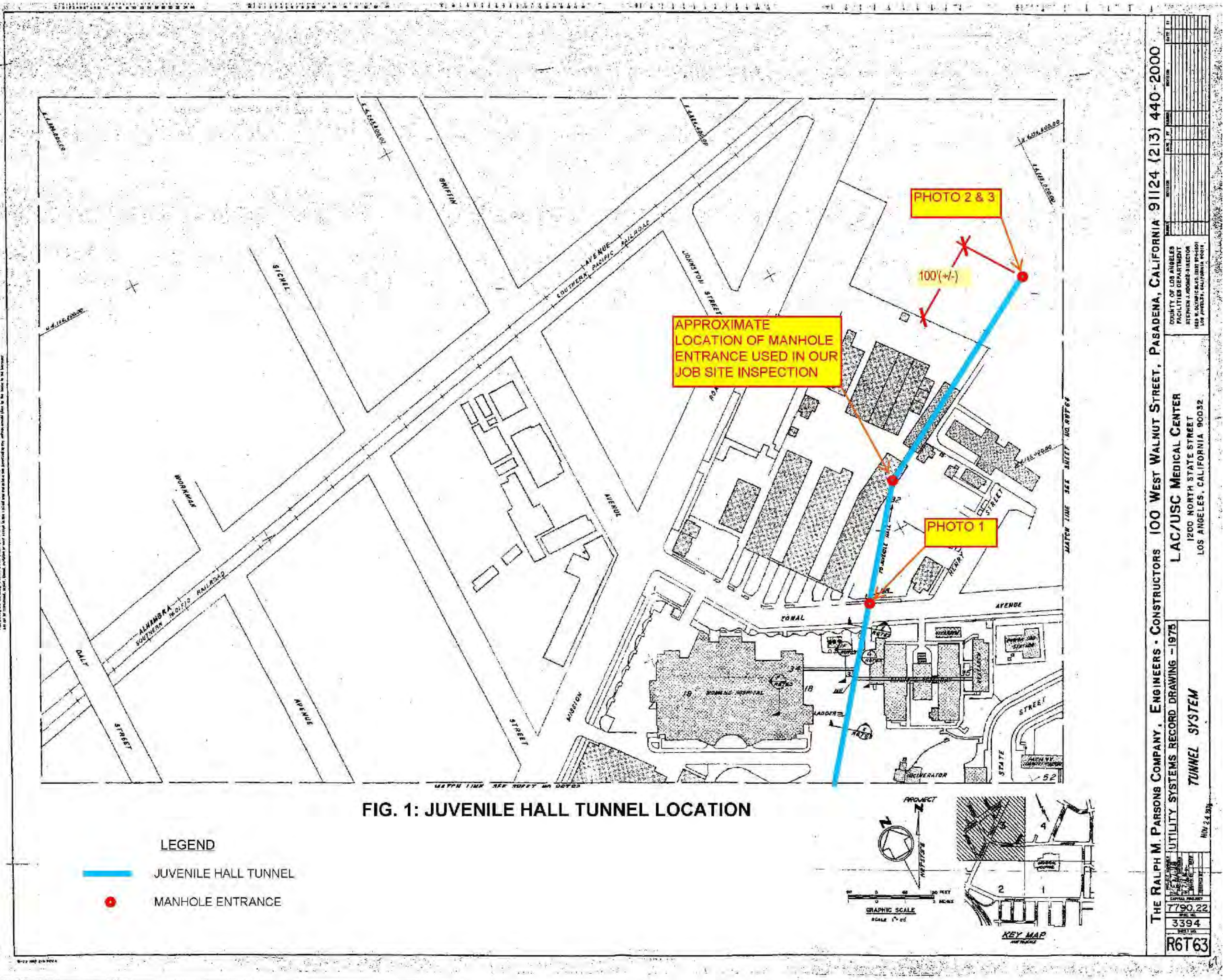
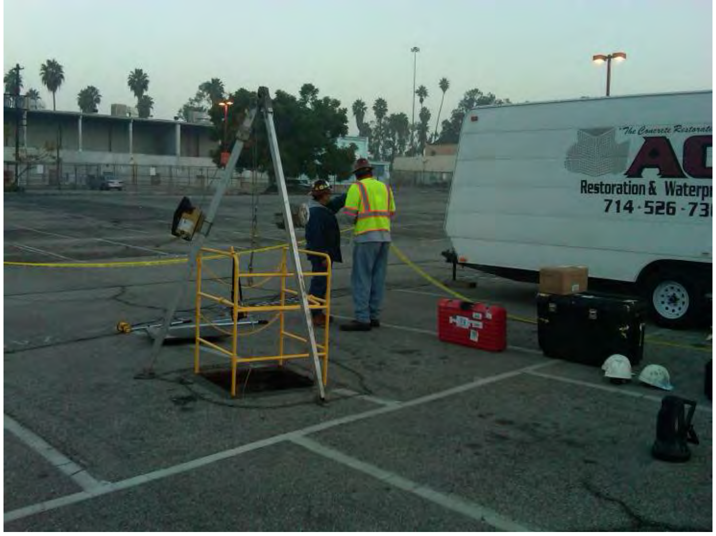


FIG. 1: JUVENILE HALL TUNNEL LOCATION

1. Tunnel Completely obstructed at Zonal Av.

2. Tunnel Completely Obstructed at 100 FT Inside Juvenile Hall

3. No Access Beyond this Point (100 FT Inside Juvenile Hall)



4. Safety Preparations at Tunnel Entry

5. Ventilation Preparations at Second Manhole

6. Tunnel View from Entry

7. Vector Corrosions Technology Entry

8. JCE Structural Engineering Group Entry

9. Marking Inside Tunnel

10. Marking Inside Tunnel

11. Measurements Inside Tunnel

12. Measurements Inside Tunnel

13. **Delamination Survey by Hammering**

14. **Delamination Survey by Hammering**

15. **Half Cell Corrosion Potential Testing**

16. Measurements after GPR Rebar Locations

17. Rebar Diameter Measurements

18. Rebar Cover Measurements

19. Core Drilling Equipment Entry

20. Core Drilling Equipment Entry

21. Core Drilling Operations

22. Concrete Core Extraction

23. Concrete Core measurements

24. Core Hole Measurements

25. PH Measurements

26. Tunnel’s Damaged Ceiling
(Concrete spalled off & rebars corroded)

27. Tunnel’s Damaged Ceiling
(Concrete spalled off & rebars corroded)

28. Tunnel's Damaged Ceiling & Shored

29. Tunnel's Damaged Ceiling
(Concrete spalled off & rebars corroded)

30. Tunnel's Damaged Ceiling
(Concrete spalled off & rebars corroded)

31. Tunnel's Damaged Ceiling
(Concrete spalled off & rebars corroded)

32. Tunnel's Ceiling Delamination (Concrete Ready to spall off)

33. Tunnel's Ceiling Delamination (Concrete Ready to spall off)

34. Tunnel's Ceiling Delamination (Concrete Ready to spall off)

35. Tunnel's Ceiling Delamination (Concrete Ready to spall off)

36. Tunnel's Damaged Walls (Concrete Spalled off & Rebars Corroded

37. Tunnel's Damaged Walls (Concrete Spalled off & Rebars Corroded

38. Tunnel's Damaged Walls (Concrete Spalled off & Rebars Corroded

39. Tunnel's Damaged Walls (Concrete Spalled off & Rebars Corroded

40. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

41. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

42. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

43. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

44. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

45. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

46. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

47. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

48. Tunnel’s Damaged Walls (Concrete Spalled off & Rebars Corroded

49. Tunnel's Damaged Walls (Concrete Spalled off & Rebars Corroded

50. Tunnel's Damaged Walls (Concrete Spalled off & Rebars Corroded

51. Tunnel Walls Delamination Concrete (Ready to Spall off)

52. Tunnel Walls Delamination Concrete (Ready to Spall off)

53. Tunnel Walls Delamination Concrete (Ready to Spall off)

54. Tunnel Walls Delamination Concrete (Ready to Spall off)

55. Tunnel Walls Delamination Concrete (Ready to Spall off)

56. Tunnel Walls Delamination Concrete (Ready to Spall off)

57. Tunnel Walls Delamination Concrete (Ready to Spall off)

58. Tunnel Walls Delamination Concrete (Ready to Spall off)

59. Tunnel Walls Delamination Concrete (Ready to Spall off)

60. Tunnel Walls Delamination Concrete (Ready to Spall off)

61. Tunnel Walls Delamination Concrete (Ready to Spall off)

62. Tunnel Walls Delamination Concrete (Ready to Spall off)

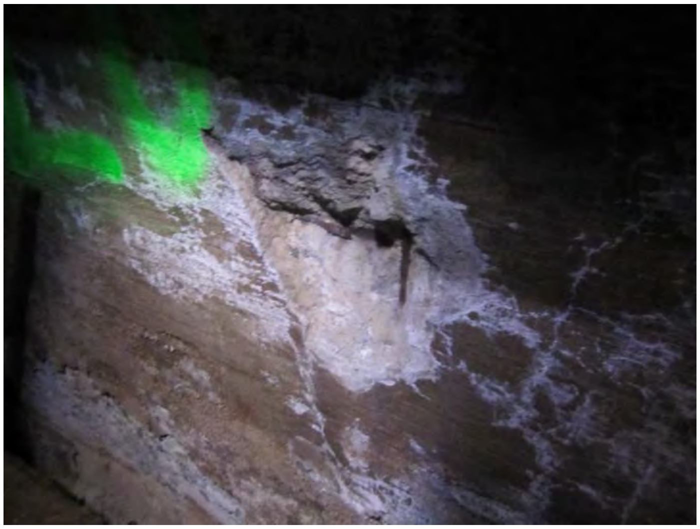
63. Tunnel Walls Delamination Concrete (Ready to Spall off)

64. Tunnel Walls Delamination Concrete (Ready to Spall off)

65. Tunnel Walls Delamination Concrete (Ready to Spall off)

66. Tunnel Walls Delamination Concrete (Ready to Spall off)

67. Tunnel Walls Delamination Concrete (Ready to Spall off)



68. Tunnel Walls Delamination Concrete (Ready to Spall off)

69. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored

70. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored

71. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored

72. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored 4

73. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored

74. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored

75. Tunnel Steam Pipe Support Completely Rusted & Not Adequately Anchored

76. Tightness Space Inside the (E) Tunnel

77. Tightness Space Inside the (E) Tunnel

78. Tightness Space Inside the (E) Tunnel

79. Tightness Space Inside the (E) Tunnel

80. Tightness Space Inside the (E) Tunnel

81. Tightness Space Inside the (E) Tunnel

82. Tightness Space Inside the (E) Tunnel

83. Tightness Space Inside the (E) Tunnel

84. Tightness Space Inside the (E) Tunnel

85. Damaged Surface parking Structure above the (E) Tunnel

86. Damaged Surface parking Structure above the (E) Tunnel

87. Damaged Surface parking Structure above the (E) Tunnel

APPENDIX D

CONCRETE CORROSION EVALUATION REPORT

BY

VECTOR CORROSION TECHNOLOGIES

Concrete Corrosion Evaluation
LAMC Utility Tunnel
Los Angeles, CA

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Jan 8, 2013

Executive Summary

Vector Corrosion Technologies conducted a concrete condition and corrosion assessment of the LA Medical Center Juvenile Hall Utility Tunnel during December 7 through 9.

The scope of this work included:

- Measuring and marking 10 ft. long sections of the tunnel for reference
- Visual photographic record of observations
- A delamination survey
- A detailed investigation of a “Good” and a “Bad” tunnel section involving
  - Core sampling for compressive strength, chemical analysis and petrographic examination
  - Electrical resistivity and reinforcing continuity
  - GPR survey to asses concrete cover and rebar spacing
  - Half-cell potential survey
  - pH testing
  - Repair of core holes

The findings of the investigation are:

1. The tunnel concrete has more than 20 percent of the surface area that is spalled or delaminated.
2. Reinforcing steel in many spalled areas is severely corroded and in need of replacement.
3. Half–cell potentials indicate that more than 90% of the reinforcing in the tested areas is either actively corroding or is at risk for corrosion.
4. The pH of the concrete has been reduced to pH <8.25 throughout the cross section in all areas tested, indicating exposure to external sulfate attack.
5. The reinforcing steel is mostly continuous, except for areas where reinforcing had rusted through or at construction joints.
6. The concrete in “Bad” areas is suffering from an advanced stage of sulfate attack.
7. The concrete is soft in many areas and crumbles when scraped with a steel tool.
8. The design compressive strength is approximately 3500 to 4000 psi
9. No foundation coatings were observed on the exterior surface of full depth cores.

10. Tunnel walls and ceiling are approximately 6 inches thick.
11. The wall reinforcement is two layers of 3/8-inch square reinforcing bars with vertical bars at 8-inch spacing and horizontal bars at 14 inch spacing.
12. The ceiling reinforcement is one layer of 3/8 inch square reinforcing bars on the bottom face with bars at 8 inch spacing in both directions
13. The concrete cover is approximately 1.5 to 2 inches from both faces.

The tunnel concrete is suffering from external sulfate attack. This distress mechanism causes the concrete to crack, soften, and lose strength over time. The degree of damage varies throughout the structure, with some areas in an advanced state of sulfate attack. Cores extracted from good areas indicate that some sections of the concrete still have reasonable compressive strength. However, those same cores also had very low pH values, indicating that the reinforcing steel in the “Good” concrete is in a corrosive environment. Petrographic examination and chemical analysis confirmed the presence of high concentrations of soluble sulfate in “Bad” areas, and moderate amounts in “Good” areas.

Visual observations of severely corroded reinforcing and large areas of delamination in “Bad” areas means that a significant portion of the tunnel structure needs to be repaired/strengthened if the tunnel is to remain in service. Cathodic protection of the reinforcing steel will be required as part of any repair scheme to prevent continued corrosion damage. A budgetary figure for the cathodic protection portion of any repair scheme is in the range of $300,000 to $400,000.

The remaining service life of the existing tunnel is most likely less than 5 years, due to the progressive nature of sulfate attack. In some areas of the tunnel the service life is already exhausted. If strengthening repairs are performed on the “Bad” areas and cathodic protection is provided, it is feasible that the tunnel could last another 10 to 20 years. However, additional testing is recommended prior to committing to this course of action.

It is recommended that the Medical Center consider abandoning this tunnel instead of repairing it. If the tunnel is going to be repaired, a cathodic protection system will be required to prevent continued damage to the “Good” areas.

TABLE OF CONTENTS

Introduction

During December, 7 to 9 2012, Andrew Broecker and Clarence Zimmel from Vector Corrosion Technologies conducted a condition assessment of the utility tunnel for the Los Angeles County Medical Center in Los Angeles, California. Both men are certified NACE CP-2 cathodic protection testers with considerable concrete repair and restoration experience. The investigation principal investigator was Mr. Matt Miltenberger, P.E.

The investigation was focused on a 400 foot length of tunnel located under the parking lot adjacent to the juvenile detention facility. The tunnel was approximately 100 years old and piping replacement is needed. The tunnel dimensions are approximately 6’-6” tall and 4’ wide,. There were many areas of spalling, cracking, and delamination observed throughout the 400 ft. length of tunnel evaluated.

The purposes of this investigation were to:

1. assess the extent of reinforcing steel corrosion activity ;
2. determine the concrete strength, thickness, and reinforcing pattern
3. determine the cause of the concrete deterioration, and
4. quantify the amount of concrete repair required to rehabilitate the tunnel

This condition assessment is intended to describe the current condition of the reinforcing steel and concrete in this structure. The results of this assessment are intended to provide enough data to determine if cathodic protection is a viable option for this structure. This report will also describe which repair solutions are best suited for this particular structure,

Condition Assessment

Scope of Work

Vector worked closely with physical plant personnel and other contractor team members to ensure that this investigation was carried out safely. Prior testing of the tunnel air identified hydrogen sulfide gas, H_2S, indicating that the tunnel requires constant ventilation. In addition, the facility manager indicated that the old pipe insulation was believed to contain asbestos. The contracting team was comprised of Vanir Construction (project management), JCE Engineers (Structural), ME Engineers, (Mechanical), ACE Restoration and Waterproofing (ventilation), and Focus Environmental (Asbestos abatement).

Vector's scope of work was focused on investigating the causes of the deteriorating concrete and rebar corrosion activity in the utility tunnel. Once the tunnel ventilation was in place and the asbestos hazard assessment determined that the tunnel environment was acceptable to work in with appropriate personal protection equipment, Vector began the investigation.

The work began by marking stations every 10 ft. along the tunnel for the entire 400ft of tunnel. For the purposes of this investigation "Station 0" was chosen to be located at the access hatch where the tunnel crosses under Zonal Avenue. "Station 40" was near the stairs where the tunnel entered the juvenile hall facility. The initial investigation was comprised of a visual, photographic, and delamination survey of the entire 400ft length of tunnel.

After the initial survey, two 10ft long sections of the tunnel were chosen for detailed sampling and testing. One location was selected with little visual deterioration (Test Area #1, section 13-14), and another location was selected with large amounts of deterioration (Test Area #2, section 19-20). Further testing carried out on these two sections included

- Ground Penetrating Radar scans;
- half-cell corrosion potential testing;
- electrical continuity testing;
- pH testing; and
- core sampling for subsequent laboratory testing.

Visual Inspection and Delamination Survey

Upon arrival to the site the first step was to identify stations along the length of the tunnel and then perform a visual assessment and delamination survey. These procedures are a fast and effective method to gauge the condition of the concrete in a large area. This information was reviewed with JCE Engineers to select the two representative areas for more detailed investigation.

The visual assessment consisted of a detailed walkthrough of the structure. While performing the visual assessment cracks, spalling, efflorescence, and general concrete deterioration was located and noted. While performing the visual assessment, the delamination assessment was performed concurrently. The delamination testing was performed by striking a hammer against the concrete and listening to the sound in accordance with ASTM D4580-03. If the hammer impact rings the concrete is sound, if the impact results in a lower pitch, "hollow" sound a delamination is present.

Delaminations were found throughout the entire length of the tunnel. Approximately 22 percent of the total 6800 ft^2 was found to be delaminated or spalled. The delaminated area in each 10 ft. "Station" was recorded in tabular format and can be found in 'Appendix A'.

In many spalled concrete areas that exposed the inner reinforcing steel layer, so sounding was not necessary. In most spalled locations the reinforcing steel had a very reduced cross section or had completely corroded such that the steel bar severed. Total reinforcement replacement will be required in these areas.

Figure 1 - Severely corrded reinforcing in spall at Station 21-22

Figure 2 - Severely corroded tunnel ceiling slab reinforcement

Additional photographs are available in Appendix

Depth of Concrete Cover

The depth of the concrete cover over the reinforcing steel was determined in all areas where samples were extracted. The depth of concrete cover measurement determines the location of the reinforcing across the concrete thickness. Often shallow reinforcing steel is subject to a more corrosive environment, which leads to faster concrete deterioration. The reinforcing steel was located using Ground Penetrating Radar (GPR). The cover depths were also confirmed in the areas of the tunnel where the steel is exposed due to spalling. The depth of cover is necessary when analyzing chloride contamination profiles and carbonation profiles to determine the potential for corrosion of the steel.

Ground Penetrating Radar

Ground Penetrating Radar (GPR) allowed for a non-destructive view of the concrete reinforcement (rebar) depth, orientation, and spacing. In addition the GPR was used to provide a rough estimate of the tunnel wall thickness and also locate any unanticipated objects beneath the surface of the concrete. GPR was used to pre-screen each predetermined core location prior to drilling and extraction operations.

The Ground Penetrating Radar (GPR) sends an electromagnetic pulse into the concrete and subsurface objects cause reflections that are acknowledged by the GPR receiver. The collected data can be extracted as 2-D plots as shown in Figure 3 below. The information gained from the GPR scans is listed below:

- Rebar Spacing: Vertical bars are at 8”, Horizontal bars are at 14”
- Rebar Cover Depth: Concrete cover is consistently between 1” and 2”.
- Rebar Size: 3/8” square bar was observed in all locations.
- Walls: There are 2 layers of reinforcing steel. The second layer is the same size bar (3/8”) as the first layer with approx. 1”-2” of cover from the outside face of the tunnel. Vertical bars are space 8 inches apart; horizontal bars are spaced 14 inches apart.
- Ceilings: There was one layer of reinforcing steel located near the bottom. Rebar spacing was 8 inches in both directions.
- Concrete Thickness: Approximately 6” walls and ceilings. (Confirmed by both the GPR and core samples) Note: no foundation coatings were noted on the soil side.

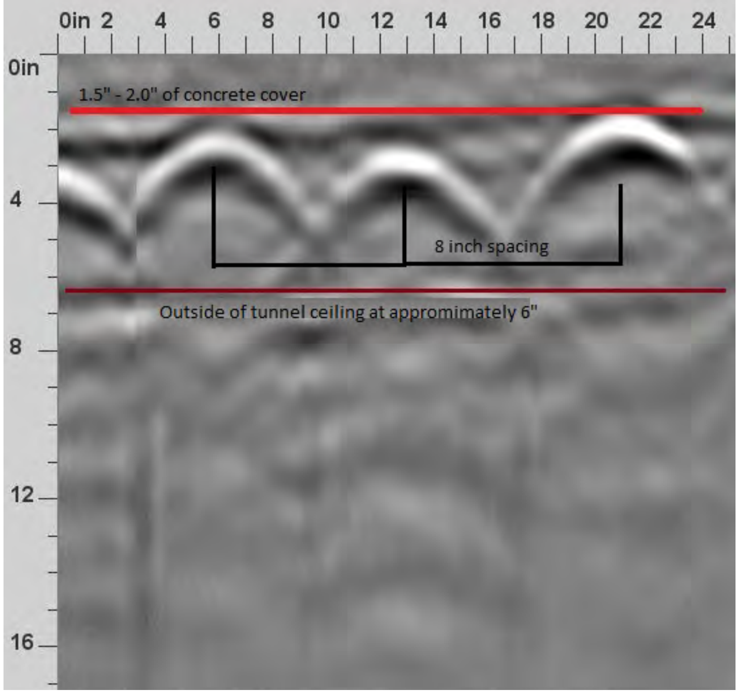


Figure 3: Typical GPR scan of the tunnel ceiling showing one reinforcing layer

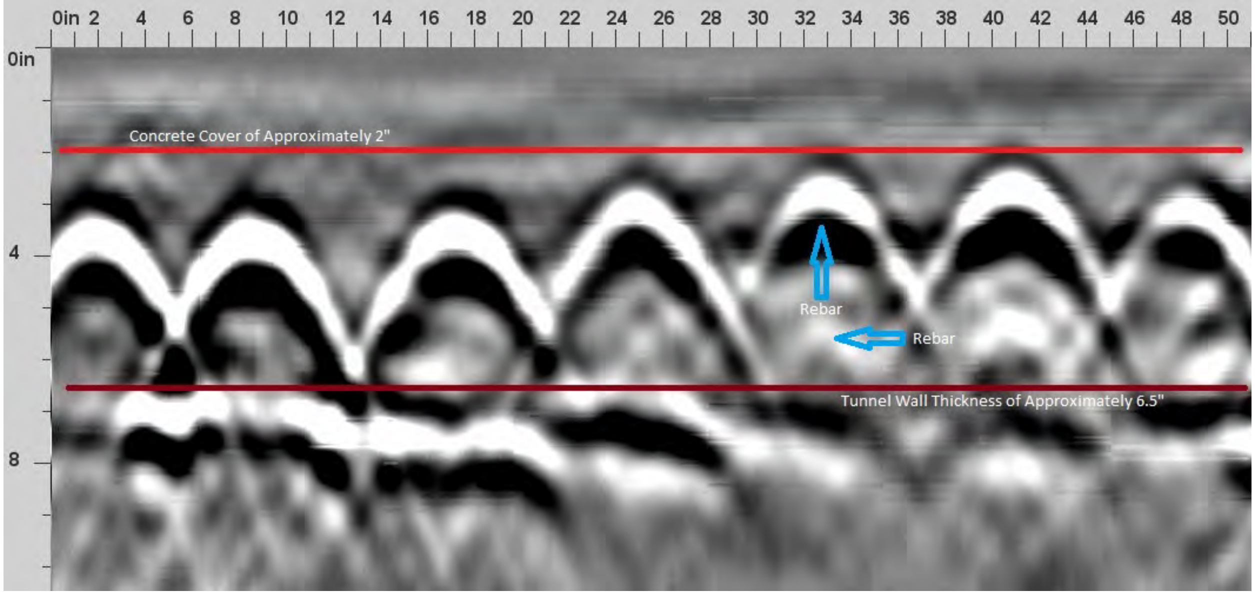


Figure 4 - Typical GPR image of tunnel wall showing two reinforcing layers

Electrical Continuity

Electrical continuity of the reinforcing is necessary for possible future corrosion mitigation by cathodic protection. Electrical continuity is verified by contacting various steel elements with lead wires attached to a high impedance multi-meter using the DC milli-volts and/or resistance settings. As per ACI 222R-01 Standard in Section 4.3.1.6a, if the potential difference between the reinforcing bars is less than one (1) mV, then the reinforcing steel is deemed electrically continuous.

Electrical continuity was tested at multiple locations at each inspection location. Findings from the electrical continuity testing are as follows:

- All of the reinforcing steel within the “Good” Test Area #1 (13-14) was found to be continuous.
- Most of the steel in “Bad” Test Area #2 (19-20) was found to be continuous except for a couple discontinuous bars near tunnel section 20-21. (Large amounts of spalling and corrosion are present in section 20-21)
- Continuity was tested across three (3) expansion joints. The steel was found to be discontinuous across each of these expansion joints.

Conclusion:

The reinforcing steel in the tunnel is likely to be electrically continuous with the exception of heavily spalled/corroded areas, or across expansion joints.

Half-Cell Corrosion Potentials

The half-cell is a reference electrode that consists of a metal rod immersed in a solution of its own ions such as a copper rod in a copper sulfate solution. The half-cell is a reversible reaction that has a stable galvanic potential or reference voltage. The reinforcing steel also has a galvanic potential that varies depending on the corrosion condition of the steel. When the reference electrode is placed in contact with the concrete surface, the voltage difference between the reference electrode and the reinforcing steel can be determined using a voltmeter. A voltage is generated because the different metals (copper and steel) are at different positions on the electrochemical series. When the cell is moved along the surface of the concrete, the voltage difference between the rebar and the reference electrode indicate the corrosion conditions of the steel within the concrete. This test yields a number known as a corrosion potential, which provides an indication of the probability for corrosion activity of the reinforcing steel within the concrete.

Potential surveys are normally carried out on a regular interval grid. For this particular situation, measurements were taken on approximately 16 inch grid spacing along the tunnel walls and ceiling over the 10 ft. long tunnel test section. The half-cell measurements were taken using a standard copper-copper sulfate ($Cu\text{-}CuSO_4$) reference electrode. A description of the testing procedure is outlined in ASTM C 876 “Corrosion Potentials of Uncoated Reinforcing Steel in Concrete”. The following table has been developed for evaluating $Cu\text{-}CuSO_4$ half-cell potentials.

Table 1 - Interpretation of Half- Cell Corrosion Potential Measurements (ASTM C876)

Reading vs. Cu-CuSO$_4$ half-cell	Probability of Corrosion Activity
More positive than -200 mV	Low (< 10% probability of corrosion activity at the time of testing)
-200 to -350 mV	Uncertain (50 % probability of corrosion activity at the time of testing)
More negative than -350 mV	High (> 90% probability of corrosion activity at the time of testing)

For the purposes of this investigation, all half-cell readings were recorded in mV vs. CSE (copper-sulfate reference electrode). When reviewing the results of the corrosion potential survey, the majority of the readings were in the high probability of corrosion activity range. This is indicating high levels of corrosion activity currently underway in reinforcing steel of the tunnel. This is true even in Test Area #1, which is not currently showing as many visual signs of corrosion as Test Area #2. See 'Appendix C' for specific half-cell readings at each location.

Figure 5 - Half-cell Corrosion Potential Testing

Table 2 - Summary of Corrosion Potential Measurments

		Half-Cell Survey Readings (mV DC vs. CSE)			
Location	**Total Readings Taken**	**Low Corrosion Probability (Less than 10%)**	**Medium Corrosion Probability (50%)**	**High Corrosion Probability (More than 90%)**	**% Medium Probability or Higher**
Test Area #1 (13-14)	96	0	3	93	100%
Test Area #2 (19-20)	96	9	74	13	90%

On Site pH Testing

On site pH testing was conducted in multiple locations in the tunnel. Rainbow Indicator by Germann Instruments was sprayed on the freshly broken concrete surfaces of the tunnel. The color that the sample turns to when the indicator dries indicates its pH. A color scale was used to determine the pH of each sample. All of the concrete samples sprayed were found to have a pH of approximately 6-7.

The water pooling on the tunnel floor was also tested for pH using pH strips and a color scale. The strip was dipped into the water and then its color was compared to the color scale to obtain its pH. The pH of the water was found to be approximately 7.

Figure 6 - pH testing of concrete

Core Samples

Core samples were obtained at each of the test area for chemical analysis, petrographic analysis and compressive strength testing. Three cores where taken from each of the two detailed testing areas. Each of the walls in the testing area had at least one core extracted, and cores where extracted at different heights. This pattern was selected to provide a better overall representation of the tunnel condition and to help identify if the tunnel wall was tapered.

Two cores were selected for compressive strength in each of the two detailed testing areas. These cores where full depth. Each core location was documented along with the length measurement to provide a benchmark for the wall thickness in that area. Photographs of the core locations along with their depths can be found in Appendix E.

Each detailed testing area also had a core extracted for chemical and petrographic analysis. One core was taken in an area that appeared to be representative of the general condition of the tunnel, while the other core was taken directly over a crack. By taking one core over a crack it can better be determined if the concrete deterioration is being cause be an external contaminate leaching in to the concrete. This core "P19-20S" intersected a delamination and cracked into pieces upon extraction.

During the sample collection it was noted that there is two rebar mats in this structure (Picture #68 Appendix D). Upon removing one of the cores for petrographic analysis it revealed a delaminated lay within the concrete wall (Picture #69 Appendix D). It can also be noted that none of the cores taken had a membrane between the wall and the soil and that the wall was approximately 5"-6.5" at each testing location.

Upon completion of the core extraction cores were securely packed and shipped to Tourney Consulting Group for further analysis.

Laboratory Testing

Compressive Strength

The compressive strength of the cores extracted from the good "Good" area at Station 13-14 and from the "Bad" area at Station 19-20 were similar. Compressive strengths were approximately 5000 psi as tested in the as-received moisture condition in accordance with ASTM C 42 procedures. This partially moist condition provides strength results that are higher than if the cores were saturated. The core strengths indicate that the concrete design strength, f'c, is between 3500 to 4000 psi.

Depth of Carbonation

The depth of carbonation determined using phenolphthalein indicator on the cores indicates that the pH of entire concrete section is less than pH 8.25. This finding indicates that 100% of the steel is subject to corrosion because the normally alkaline environment inside the concrete no longer exists. The probable causes for this condition are either the entire wall thickness is carbonated (unlikely), or external sulfate attack has decalcified the entire wall section.

Chloride Content

Water soluble chloride levels were consistently low ~30 ppm at Station 13-14, and were slightly elevated in Core 19-20. There is a small chloride gradient entering from the exterior at station 19-20 which is consistent with concrete in contact with soil containing chloride in the ground water. The chloride levels at the depth of the inner layer of reinforcing were insufficient to cause corrosion of reinforcing in sound concrete. However, any chloride present will accelerate corrosion in carbonated concrete.

Figure 7 - Water-soluble chloride ion content

Petrographic Analysis

The petrographic examination indicates the following:

1. Salt crystal formations developed on both cores upon drying after wetting for 48 hours. More crystals appeared on core P19-20 than on core P13-14. Salt crystals appeared at micro cracks and at the perimeters of aggregates. This indicates that soluble salts are available within in the concrete. This finding combined with a fully decalcified concrete cross-section point to advanced stages of external sulfate attack.
2. The cement paste is soft and appears to have a w/c of approximately 0.60. No signs of pozzolans were reported. This is as expected for early 90+ year old concrete.

3. Reinforcing was 3/8 inch square bars. All reinforcing bars observed were corroded. Rust was observed in cracks adjacent to the reinforcing bars.
4. The aggregates are mostly sound with some particles exhibiting signs of alkali silica reaction. The amount of ASR observed is considered negligible.

Sulfate Content

Testing for water-soluble sulfate indicates that both cores contained free sulfate, which is indicative of external sulfate attack. More sulfate existed in the “Bad” area, represented by core P19-20 than in the “Good” area represented by core P13-14. In particular, the water soluble sulfate profile for Core P19-20 indicates that the sulfate content in the “Bad” location is very high on both the interior and exterior faces. This phenomenon supports the assertion that free sulfate is entering the concrete from the exterior and that sulfate crystals are precipitated upon drying as the moisture moves toward the interior face.

For concrete to be dimensionally stable, very little water-soluble sulfate (< 50 ppm) should be present after cement hydration. In this case, considerable quantities of free sulfate exist: >150 ppm for core P13-14, and >1000 ppm for core P19-20.

Figure 8 - Water-soluble sulfate profile

Table 3 - Water-soluble chloride and sulfate ion test results

	"Good Area" P13-14		"Bad Area" P19-20	
Depth	Cl^- ppm	SO_4^{2-} ppm	Cl^- ppm	SO_4^{2-} ppm
(interior) 0 to 1/2	34	291	50	8692
1 to 1.5	26	225	39	930
2.5 to 3	27	162	82	284
3.5 to 4	30	176	219	783
5 to 5.5 (exterior)	35	133	164	3399

Electrical Resistivity of Concrete

The cores used for petrographic examination were also used for electrical resistivity using an AC resistance meter. The resistivity of the concrete was approximately 33,000 ohm-cm. This relatively high resistivity indicates that a smaller than normal cathodic protection anode spacing will be required.

Summary of Findings

1. The normally alkaline environment (pH>12) inside the concrete that normally protects steel has been destroyed by the decalcification process associated with external sulfate attack. This decalcification process has reduced the alkalinity of the concrete below pH 8 across the entire concrete cross-section, indicating that all the reinforcing in this tunnel is in a very corrosive environment.
2. Half-cell corrosion potential measurements indicate that more than 90% of the reinforcing steel in both the “Good” and “Bad” test areas was at risk for corrosion activity.
3. More than 20% of the tunnel surface area had spalled concrete or delaminations caused by corrosion activity. In many areas it was observed that corrosion had consumed the entire reinforcing steel cross-section.
4. The reinforcing pattern was as follows:
    - Walls: 6 inch thick concrete wall with formed surfaces interior and exterior; two layers of 3/8-inch square bars; vertical bars are spaced 8-inches on center; horizontal bars are spaced 14-inches on center; concrete cover was approximately 1.5 to 2 inches from both faces.
    - Ceiling: 6 inch thick concrete slab with one layers of 3/8-inch square bars spaced 8-inches on center in both directions; concrete cover was approximately 1.5 to 2 inches from the bottom surface.

Conclusions

This tunnel structure requires extensive rehabilitation or replacement. The observed current condition with more than twenty percent of the concrete surface spalled or delaminated and reinforcing bars that are completely corroded through means that repair would essentially mean rebuilding or strengthening some sections of the tunnel. The service life of these areas can be considered exhausted.

The presence of advanced sulfate attack means that the concrete itself is deteriorating. Over time, the concrete in the “Good” areas will become softer, and the inherent strength of the concrete will diminish. The conditions observed in the “Bad” areas are indicative of what will spread to the “Good” areas. As the process continues, the cement paste will continue to crack, leading to progressive weakening of the tunnel structure. Fortunately, the current strength of the tunnel concrete is reasonable, which indicates that the tunnel concrete can probably last a few (~5) more years.

The finding that even the visually “Good” areas are completely decalcified due to advanced sulfate attack means that all the reinforcing steel is in a very corrosive environment, and that concrete distress will continue. This was confirmed by half-cell corrosion potential measurements.

In order to prevent further deterioration of the concrete from reinforcement corrosion, a cathodic protection system would be required. There are two generic system categories: galvanic cathodic protection systems (GCP) and impressed current cathodic protection systems (ICCP). Both system types can work in this environment. The budgetary cost for a cathodic protection system for this structure would be in the range of $300,000 to $400,000. Design option analysis is required to determine the most appropriate system based on the required design life and system maintenance options. This level of cathodic protection design is beyond the scope of this investigation.

The current condition of the tunnel structure means that a significant investment in the tunnel structure is required prior to installation of a new piping system. Unfortunately the concrete material is in an advanced state of distress, and is near the end of its useful life. At best, the current concrete structure may last another 10 to 20 years if concrete repairs and strengthening are completed, and a cathodic protection system is installed to halt further reinforcement deterioration. However, this approach essentially only delays the inevitable because eventually the concrete will begin to crumble due to continued sulfate attack distress, and a new tunnel structure will be required.

The critical element in this decision is the very real risk that the tunnel concrete will fail before the new piping is ready for replacement. Unfortunately, it is not possible to determine a deterioration timeline from the information obtained at this snapshot in time. Additional testing and review previous petrographic examination of the concrete are needed to project the future distress timeline.

In closing, it is recommended that the Medical Center consider abandoning this tunnel instead of repairing it. If the tunnel is going to be repaired, a cathodic protection system will be required to prevent continued damage to the "Good" areas.

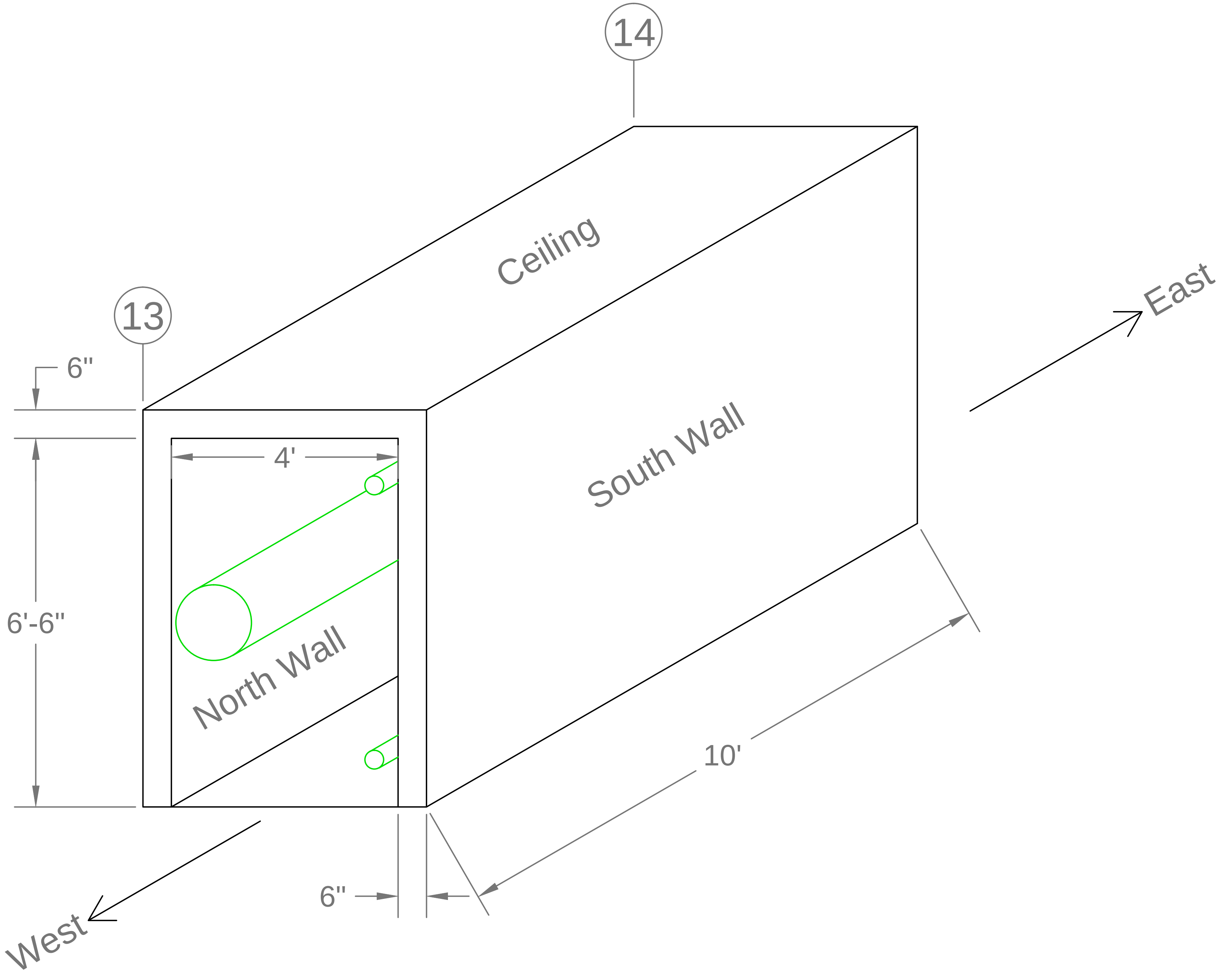
Appendix A:

Visual and Delamination Survey Log

Tunnel Section	% Delaminated or Spalled (North Wall)	% Delaminated or Spalled (South Wall)	% Delaminated or Spalled Total	Square Footage Delaminated or Spalled Total	Spalling	Delamination	Soft, Poor Quality	Exposed Reinforcing Steel	Eflorescence	Photographs	Notes
0-1	10	25	17.5	29.75			x			5,87	West end access/ventalation near road
1-2	15	10	12.5	21.25	x	x	x	x	x	11	
2-3	15	5	10	17	x	x	x				
3-4	5	15	10	17	x	x	x	x		12,13,14,15,16,17,18,19,20	
4-5	5	10	7.5	12.75	x	x	x				
5-6	10	5	7.5	12.75	x		x			21,22,23	
6-7	0	5	2.5	4.25	x		x				
7-8	5	0	2.5	4.25	x		x			24,25	
8-9	5	0	2.5	4.25	x					26,27	Rust staining from possible pipe leak
9-10	0	0	0	0							
10-11	0	0	0	0							
11-12	5	10	7.5	12.75	x	x				4	
12-13	0	0	0	0						6,7,8,9,10	
13-14	5	0	2.5	4.25	x				x	47,48,89	Test Area 1
14-15	5	5	5	8.5							
15-16	10	15	12.5	21.25	x	x		x		28,29	
16-17	15	25	20	34	x	x					Tunnel access hatch location
17-18	0	5	2.5	4.25	x		x				
18-19	5	0	2.5	4.25	x		x			51,52	
19-20	20	35	27.5	46.75	x	x	x	x	x	53,54,55,56,20	Test Area 2
20-21	45	100	72.5	123.25	x	x	x	x	x	57,58,59,60,61,91,92	
21-22	25	80	52.5	89.25	x	x	x	x	x	30,31,32,45	
22-23	15	45	30	51	x	x	x	x	x	43,44	
23-24	25	10	17.5	29.75	x	x		x			
24-25	25	40	32.5	55.25	x	x		x	x	33,35	
25-26	50	100	75	127.5	x	x		x	x	34,36,37,38	
26-27	25	30	27.5	46.75	x	x		x	x		
27-28	5	5	5	8.5		x	x				
28-29	15	10	12.5	21.25	x	x	x	x			Access/ventalation location
29-30	80	10	45	76.5		x					
30-31	20	60	40	68	x	x			x	42	
31-32	25	5	15	25.5		x			x		
32-33	25	50	37.5	63.75	x	x		x			
33-34	20	50	35	59.5		x	x				
34-35	70	45	57.5	97.75	x	x		x			
35-36	45	50	47.5	80.75	x	x		x		39,40,41	
36-37	5	5	5	8.5	x	x		x			
37-38	5	5	5	8.5		x	x				
38-39	50	80	65	110.5		x	x				Stairway near corrections facility
39-40	50	50	50	85			x				
		Total:	22	1496							

Appendix B:

Test Location Drawings and Half-Cell Readings



TUNNEL & TEST AREA DIMENSIONS

Drawing Legend	
▨	Pipe Location
○	Core Sample Location
DL	Delamination
✱	Spalling
~	Crack
▬	Exposed Reinforcing Steel

Half-Cell Reading Scale: (All readings shown as mV DC vs. CSE)	
> -200	Low (<10% probability of corrosion activity at the time of testing)
-200 to -350	Uncertain (50% probability of corrosion activity at the time of testing)
< -350	High (>90% probability of corrosion activity at the time of testing)

VECTOR CORROSION TECHNOLOGIES, INC.

3822 TURMAN LOOP
SUITE 102
WESLEY CHAPEL, FL 33544

WWW.VECTOR-CORROSION.COM

PROJECT:
LOS ANGELES COUNTY MEDICAL CENTER
UTILITY TUNNEL CORROSION CONDITION ASSESSMENT

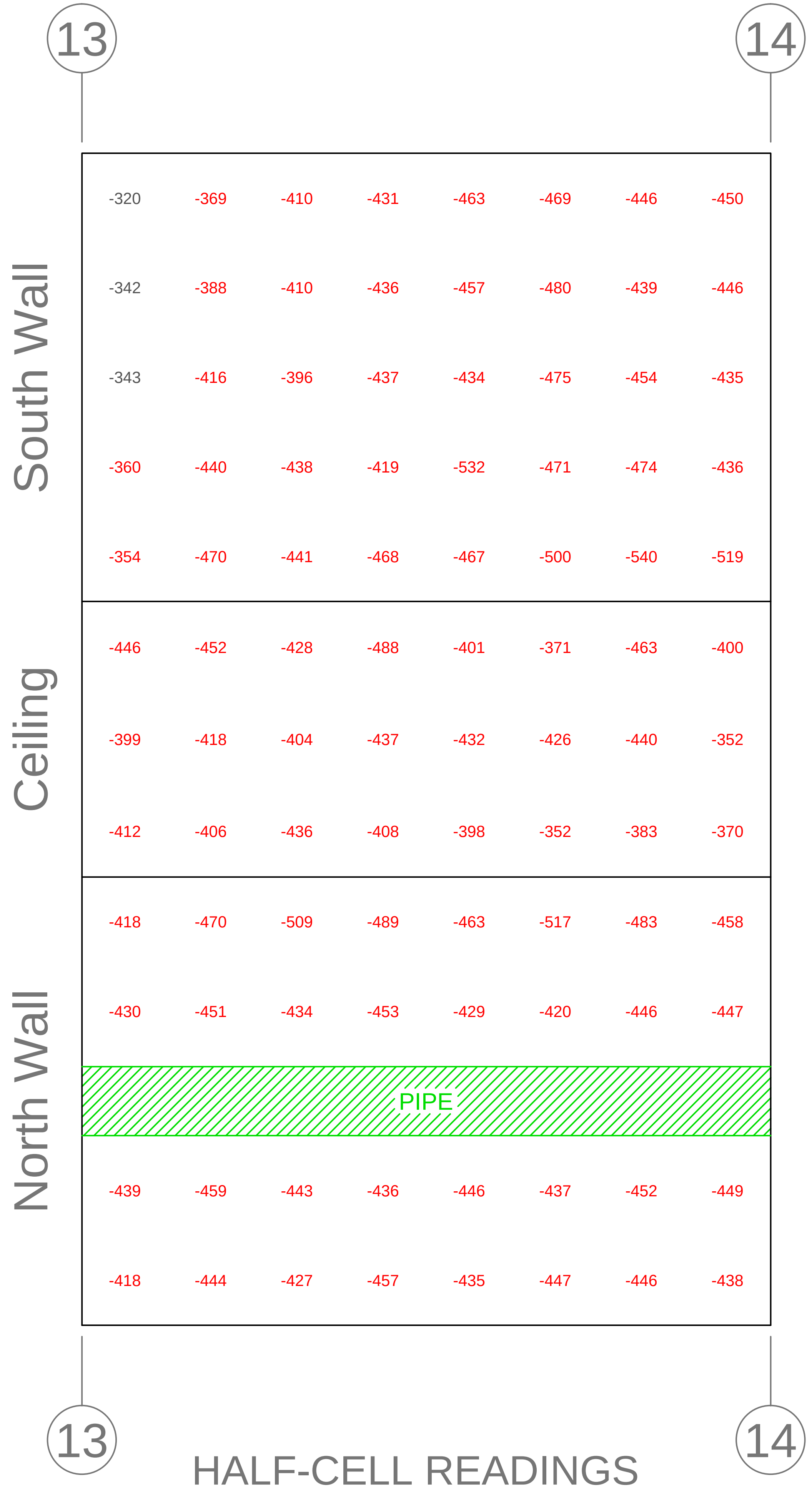
SHEET TITLE:
TUNNEL LAYOUT AND DRAWING LEGEND

SCALE:
NTS

DATE:
Dec 2012

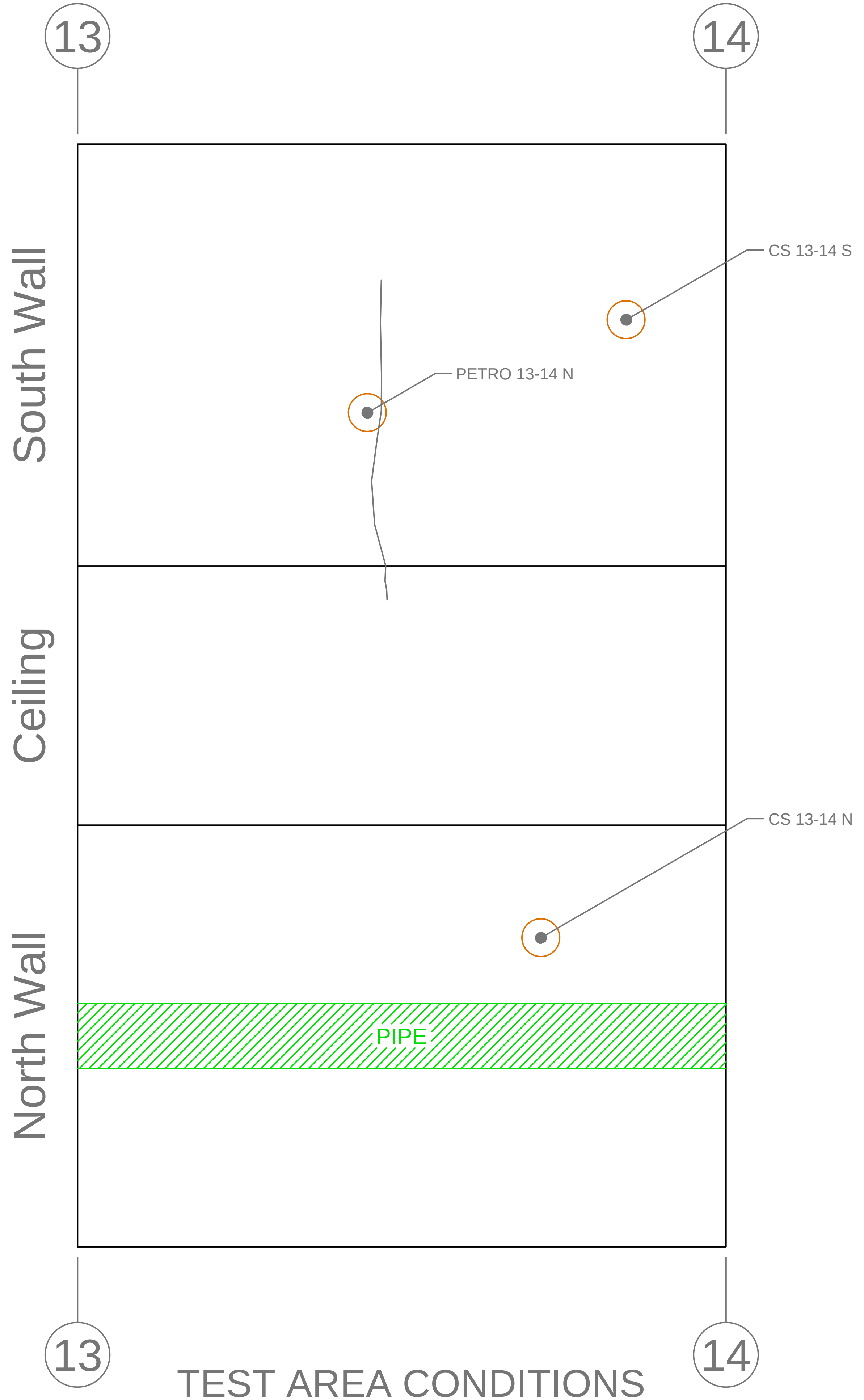
DRAWN BY:
A.S.B.

CS - 1



South Wall	-320	-369	-410	-431	-463	-469	-446	-450
	-342	-388	-410	-436	-457	-480	-439	-446
	-343	-416	-396	-437	-434	-475	-454	-435
	-360	-440	-438	-419	-532	-471	-474	-436
	-354	-470	-441	-468	-467	-500	-540	-519
Ceiling	-446	-452	-428	-488	-401	-371	-463	-400
	-399	-418	-404	-437	-432	-426	-440	-352
	-412	-406	-436	-408	-398	-352	-383	-370
North Wall	-418	-470	-509	-489	-463	-517	-483	-458
	-430	-451	-434	-453	-429	-420	-446	-447
PIPE								
	-439	-459	-443	-436	-446	-437	-452	-449
	-418	-444	-427	-457	-435	-447	-446	-438

HALF-CELL READINGS



TEST AREA CONDITIONS

VECTOR CORROSION TECHNOLOGIES, INC.

3822 TURMAN LOOP
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WESLEY CHAPEL, FL 33544

WWW.VECTOR-CORROSION.COM

PROJECT:
LOS ANGELES COUNTY MEDICAL CENTER
UTILITY TUNNEL CORROSION CONDITION ASSESSMENT

SHEET TITLE:
TEST AREA #1
STATION 13-14

SCALE:
NTS

DATE:
Dec 2012

DRAWN BY:
A.S.B.

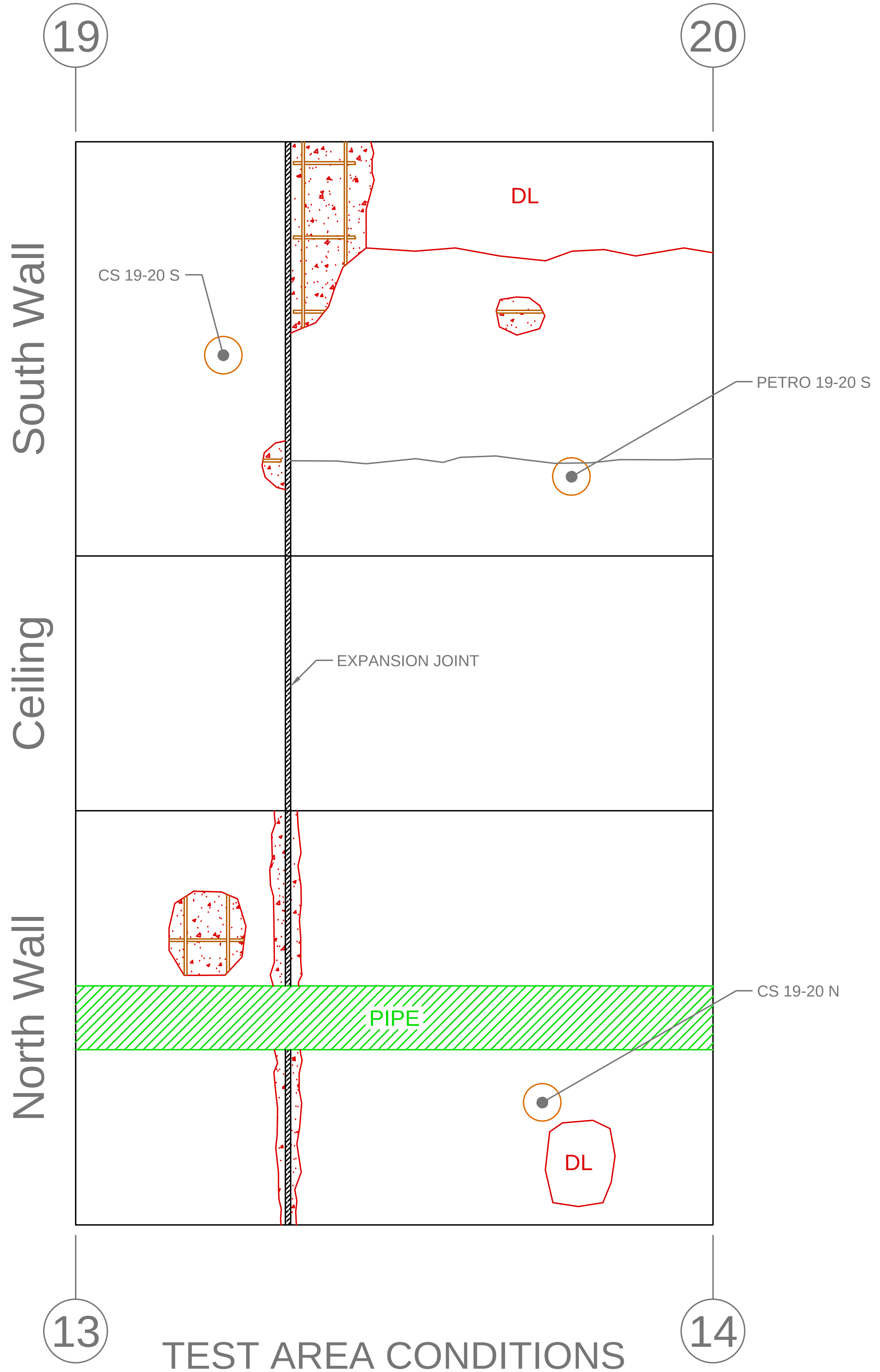
CS - 2

19 20

South Wall	-339	-325	-331	-279	-290	-298	-313	-306
	-337	-325	-327	-300	-299	-311	-282	-268
	-358	-361	-358	-340	-327	-254	-260	-208
	-369	-349	-351	-298	-295	-153	-142	-246
	-367	-338	-274	-266	-280	-238	-214	-255
Ceiling	-354	-306	-305	-317	-290	-238	-218	-117
	-325	-295	-232	-257	-257	-272	-235	-102
	-282	-255	-282	-272	-317	-254	-234	-193
North Wall	-336	-277	-243	-253	-250	-249	-208	-237
	-337	-320	-223	-146	-160	-267	-223	-269
	PIPE							
	-308	-383	-318	-187	-148	-370	-352	-330
	-398	-416	-334	-282	-300	-375	-341	-327

13 14

HALF-CELL READINGS



TEST AREA CONDITIONS

VECTOR CORROSION TECHNOLOGIES, INC.

3822 TURMAN LOOP
SUITE 102
WESLEY CHAPEL, FL 33544

WWW.VECTOR-CORROSION.COM

PROJECT:
LOS ANGELES COUNTY MEDICAL CENTER
UTILITY TUNNEL CORROSION CONDITION ASSESSMENT

SHEET TITLE:
TEST AREA #2
STATION 19-20

SCALE:
NTS

DATE:
Dec 2012

DRAWN BY:
A.S.B.

CS - 3

Appendix C:

Laboratory Testing Results

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo, MI 49048

Phone: 269.384.9980
Fax: 269.384.9981
www.tourneyconsulting.com

ASTM C42
Compression Testing of Drilled Concrete Cores

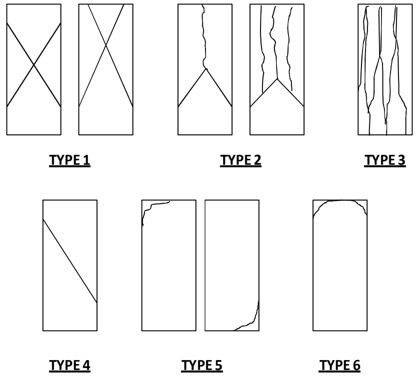
Client: Vector Corrosion Technologies
8680 W. F Avenue
Kalamazoo, MI 49009

Date Cored: 12/08/12
Date Received: 12/14/12
Date Reported: 12/27/12

Phone: 269.251.1347
Contact: Matt Miltenberger

TCG Project Number: 12141
Project Description: LA Tunnel
Sample Description: 3 3/4" Diam x 5 3/4" long cores
Sample Locations: See Core ID
TCG Technician: LW
Required Strength: 4000

Fracture Type



Core ID	Test Date	Age In Days	Avg. (2) Diam. in.	Avg.(2) Length Before Capping in.	Length After Capping in.	L/D	L/D Factor	Max Load Pounds-Force	Type Fracture	Strength psi
CS13-14N	12/27/12	N/A	3.693	4.310	4.473	1.211	0.921	64800	4	**5,570**
CS13-14S	12/27/12	N/A	3.691	5.170	5.366	1.454	0.954	57700	4	**5,150**
CS19-20N	12/27/12	N/A	3.707	5.585	5.750	1.551	0.964	55000	1	**4,910**
CS19-20S	12/27/12	N/A	3.690	6.004	6.171	1.672	0.974	56800	4	**5,170**

Note: All cores were cut square and smooth.The cores were cut to length, capped with sulfur caps and conditioned in ziploc bags for 7 days.The cores were broke with sulfur caps.

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo MI 49048

TCG
TOURNEY CONSULTING GROUP

Phone (269)-384-9980
Fax (269)-384-9981
www.tourneyconsulting.com

Proposed ASTM Test Method
Electrical Resistivity Of Concrete

Client: Vector Corrosion Technology

Date Reported: 01/10/13
Date Tested: 01/08/13
Date Received: 12/14/12

Contact: Matt Miltenberger

TCG Project No. 12141
Job Description:
Sample Description: Partial 4" x 8" cylinders soaked 24 hours in lime water prior to testing.
TCG Technician:

Specimen ID	Age Days	**Average Thickness, inch	*Average Width, inch	*Average Length, inch	Area (Square Inches)	AC Resistance, Ohm	Saturated Resistivity, Ohm-inch	Saturated Resistivity, Ohm-cm
P13-14 S	-	1.100	3.685	5.685	4.055	19000	13552	34423
P19-20 S	-	1.008	3.705	6.137	3.733	21000	12772	32442

Resistivity = (AC Resistance x Area) / Length

Note: * Average of three measurements
Note: ** Average of two readings

Larry Wachowski

Larry Wachowski

Laboratory Manager

1/10/2013

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo MI 49048

TCG
TOURNEY CONSULTING GROUP LLC

Phone (269)-384-9980
Fax (269)-384-9981
www.tourneyconsulting.com

ASTM C 1218 Water-Soluble Chloride Ion Contents (PPM)

Client: Vector Corrosion Technologies Inc.
8680 W. F Avenue
Kalamazoo, MI 49009
269.251.1347

Date Cored: 12/08/12
Date Received: 12/14/12
Date Tested: 12/21/12
Date Reported: 12/21/12

Contact: Matt Miltenberger

TCG Project No. 12141
Job Description: **Utility Tunnel**
Sample Description: Core samples were delivered to TCG laboratory by the client. The cores were cut lengthwise . One half was used for Petrographic examination. The remaining portion was cut lengthwise again at approximately 1/3 the Diameter This potion was cut to the depth increments listed below for testing.
All samples were dried and crushed to ensure all material passed a #20 Sieve. The Chloride data is reported in parts per million (ppm)
TCG Technician: RK

	Carbonation Depth	**Depth Increment (Inches)**				
Sample ID		0 to ½	1 to 1 1/2	2 1/2 to 3	3 1/2 to 4	5 to 5 1/2
Petro 12-14 S	100%	34	26	27	30	35
Petro 19-20 S	100%	50	39	82	219	164

Larry Wachowski

Larry Wachowski

Laboratory Manager

Tourney Consulting Group LLC
5200 East Cork Street
Kalamazoo MI 49048

Phone (269)-394-9980
Fax (269)-384-9981
www.tourneyconsulting.com

EPA 300.0A Ion Chromatography Method
Sulfate Content of Concrete

Client: Vector Corrosion Technologies

TCG Project No. 12141
Job Description:
Sample Description: 10 liquid samples
TCG Technicians: Bob Kronner & Larry Wachowski

Report Date: 1/10/2013
Date Received: 12/21/2012

TCG Label	Powder Weight Grams	Liquid weight Grams	Total Sample Volume ml	Sulfate (SO_4) Content mg/L	Sulfate (SO_4) Content of Powder ppm	Equivilent SO_3 Content in Powder ppm
P13-14 S (0 to ½)	10.0051	96.05	97.0	30	291	242
P13-14 S (1 to 1½)	10.0155	97.23	98.0	23	225	188
P13-14 S (2½ - 3)	10.0472	94.78	96.0	17	162	135
P13-14 S (3½ - 4)	10.0165	97.04	98.0	18	176	147
P13-14 S (5 to 5½)	10.0734	94.4	96.0	14	133	111
P19-20 S (0 to ½)	10.0103	95.94	97.0	897	8692	7243
P19-20 S (1 to 1½)	10.0055	94.04	95.0	98	930	775
P19-20 S (2-½ - 3)	10.0141	97.31	98.0	29	284	236
P19-20 S (3½ - 4)	10.0098	97.17	98.0	80	783	653
P19-20 S (5 to 5½)	10.0175	96	97.0	351	3399	2832

Concrete was pulverized and sieved through a #20 screen. The powder was digested utilizing 24 hr water extraction method as described in ASTM C1218.

Concrete Petrography Report

Prepared For:

Matthew Miltenberger

Vector Corrosion Technologies, Inc

January 08, 2013

TCG #12141

Prepared By:

Adam Rudy, Ph.D., EIT

Reviewed by:

Glenn Schaefer

3401 Midlink Drive
Kalamazoo, MI49048
(269) 384-9980 Ph. www.tourneyconsulting.com (269) 384-9981 Fax

Client:	Vector Corrosion Technologies, Inc	**Date:**	January 8, 2013
Contact:	Matthew Miltenberger	**TCG Project No.:**	12141
Project:	Utility Tunnel	**Examined by:**	Adam Rudy, PhD
		Reviewed by:	Glenn Schaefer

INTRODUCTION

Two (2) concrete samples were examined via concrete petrography. The specimens consist of 3 11/16" diameter cores. The objective of the examination was to assess the general condition of the concrete and investigate the possible cause(s) of the observed damage. Each of the two core samples was cut longitudinally to investigate the possible influence of moisture conditions, paste composition and features of the bulk and near-surface concrete. The specimen dimensions and dispositions are summarized in Table1.

Table 1 - Characteristics of pre-cast concrete specimen subjected to microscopic evaluation

Core ID.	Diameter [in.]	Length [in.]	Tests	Comments
P13-14S	3 11/16	5 ⅝	Petrography	Concrete surface is cracked and the observed crack propagates through the full depth of the core
P19-20S	3 11/16	6	Petrography	Core is extensively damaged in the top 1 ½" section. Two rebars were observed in the core at depths of 1 ¾" and 4 ¼" from the surface

This study was conducted to assess the overall concrete quality. Specifically, to identify any signs of concrete distress related to common damage mechanisms such as carbonation, delayed ettringite formation (DEF)/ sulfate attack, alkali-silica reaction (ASR) or salt crystallization (physical attack). In addition, the examination looked for indications of improper consolidation, excessive porosity, irregular voids, or other issues that might have influenced concrete quality.

SAMPLE PREPARATION AND TEST METHODS

CONCRETE PETROGRAPHY (ASTM C 856):

In preparation for the microscopic analysis, the specimens were cut longitudinally using a water-cooled diamond saw. After cutting, each core sample was lapped using a set of 5 standard abrasive discs with grits consistent with those specified in ASTM C-856 "Standard Practice for Petrographic Examination of Hardened Concrete. The petrographic examination was performed on the polished samples using a digital microscope under magnifications ranging from 20X to 200X. Note: core P19-20S was severely damaged, thus the broken concrete pieces were glued together with a fiber glass resin.

SUMMARY OF FINDINGS

The highlights of the petrographic analyses are provided below and are summarized in Table 2.

Paste Fraction

The paste fraction in the investigated cores is soft and absorbs water at a rapid rate. The estimated hardness of the paste was around 2-3 on Mohs hardness scale and was comparable to a lab reference concrete made with 0.55-0.6 water-to-cement ratio. The hardened paste in both cores wore easily and was extensively cracked. The hardened paste in both cores is contaminated with salt, which readily exuded on the surface of partially submerged samples. Freshly cut surfaces of both cores were sprayed with a phenolphthalein solution and did not result in any pink staining, which indicates that the hardened paste throughout the cores has pH lower than ~8.25. Such low pH in the concrete could be attributed to a severe paste carbonation or high concentration of salts (i.e. sulfates).

Aggregates

The fine aggregate is similar in both specimens and consists of a siliceous sand. The major types of fine aggregates include: quartz, rheolite, feldspar and andesite. The fine aggregate in both cores seems to be coarse graded. The sand observed in the investigated samples has deleterious particles, which are susceptible to alkali-silica reaction (ASR). However, the intensity of observed ASR in the sand was minor. All deleterious sand particles have cracking and in the worst cases exuded small amount of gel into surrounding cracks.

The coarse aggregate in the investigated cores is siliceous crushed rocks, which consists of quartzite, granite, diorite, andesite and schist. The observed top size of coarse aggregates varies between ¾" in core P13-14S to 1" in core P19-20S. In general, the siliceous aggregates are hard to medium-hard, sub-equant to elongate and have angular to sub-angular edges. The coarse aggregate is well graded in core P13-14S and gap-graded in core P19-20S. The bond between coarse aggregates and hardened paste is fair in both cores.

Many coarse aggregates in both cores are cracked, but only a few particles showed minor signs of alkali-silica reactivity. In the worst cases (core P13-14S), the cracks observed in the coarse aggregates propagated into hardened paste and the rocks exuded alkali-silica gel into these cracks and on the lapped surface. In general, the ASR in the cores is minor-to-negligible.

Air Voids

In general, the cores have approximately 3% of total air content and the observed air voids are entrapped. The air voids in core P13-14S are free from deposits, however a small number of voids in core S19-20P are partially filled with crystalline salts.

Reinforcing Steel

Core P19-20S has two reinforcing steel bars at depth of 1 ¾” and 4 ¼” from the surface. Both rebars show signs of corrosion, however the rebar located at a depth of 1 ¾” shows more deterioration with corrosion products deposited into surrounding micro-cracks.

Cracking and Micro-cracking

The most extensive cracking was observed in core P19-20S, however due to sample damage in the top 1 ½” section of this core, it is difficult to determine the origin of the observed macro-cracks. Core P19-20S also has wide spread macro-cracks in the bulk paste, in-between the two rebars. In addition, a number of micro-crack were observed in core P19-20S around the rebar at a depth of 1 ¾” from the surface. Many of the observed micro-crack was filled with rust corrosion products. On the other hand, only a single macro-crack and infrequent micro-cracks were observed in core P13-14S. The macro-crack in core P13-14S runs longitudinally across the core and splits into two smaller cracks at a depth of 4 ½” from the surface. The macro-cracks observed in both cores are free from deposits.

Alkali-Silica Reaction (ASR)

Minor-to-negligible signs of ASR were observed in the investigated samples. Only a few coarse aggregates in core P13-14S showed evidences of alkali-silica gel and a small number of sand particles in both cores showed reaction rims and gel formation. Based on the microscopic observations it is believed that the ASR is minor in the cores and did not contribute significantly to the observed cracking and damage.

Other Secondary Deposits

Both samples exuded substantial amounts of salts on the lapped surfaces after being partially submerged in water for 2 days. The exuded deposits are mainly crystalline (also very small amounts of gel was found in core P13-14S) and easily dissolve in water. It was reported by the client that the concrete sample were obtained from the utility tunnel. It is probable that the observed deposits consist of sulfate salts.

CONCLUSIONS

Based, on the amount of crystalline deposits exuded on the surfaces and the poor quality of hardened paste in both cores it is likely that the concrete experienced external sulfate attack. The sulfate salts typically involved in concrete deterioration are thenardite and mirabilite. These salts can dissolve and crystallize in concrete pores and cracks, causing paste softening and concrete deterioration.

Table 2 – Summary of findings from petrographic investigation

TCG Core No.	P13-14S	P19-20S
Paste Quality	Fair, soft, absorption is high, carbonation was measured through the full depth of the core, small amounts of crystalline salts were exuded on the surface of partially submerged sample	Poor, soft, absorption is high, carbonation was measured through the full depth of the core, significant amounts of crystalline salts were exuded on the surface of partially submerged sample
Cracking	Extensive macro crack through the full depth of the core, the crack propagated in the hardened paste and paste-aggregate interface. Sporadic micro-cracks in the bulk paste were observed	Extensive vertical and horizontal macro cracks were observed through the full depth of the core, the cracks propagated in the hardened paste and paste-aggregate interface. Sporadic micro-cracks in the bulk paste were also observed
Air Content	Air content is low (3%), no secondary deposits in the air voids were observed	Air content is low (3%), deposits of crystalline salts in the air voids were sporadic
Consolidation	Good, even aggregate distribution, no bleed channels or air pockets	Fair, aggregate distribution is not even
Fine Aggregate	Good, siliceous sand with small amount of ASR susceptible particles, sand seems to be coarse graded	Good, siliceous sand with small amount of ASR susceptible particles, sand seems to be coarse graded
Coarse Aggregate	Generally hard, siliceous in composition, some coarse particless are cracked. A few quartzite particles showed signs of alkali-silica reactivity with gel formation	Generally hard, siliceous in composition, some coarse particles are cracked. Coarse aggregates are gap-graded
Aggregate Bond	Fair, a significant number of aggregate shows gaps in the paste-aggregate interface	Fair, a significant number of aggregate shows gaps in the paste-aggregate interface
ASR	Minor in the fine aggregates and negligible in the coarse	Minor in the fine aggregates and negligible in the coarse
Other Deposits	Moderate amount of crystalline deposits, which exuded on the surface of partially submerged	High amount of crystalline deposits, which exuded on the surface of partially submerged
Overall Condition	In general, the concrete is in fair condition	In general, the concrete is in poor condition

RESULTS OF PETROGRAPHIC EXAMINATION

Sample P13-14S

GENERAL CONDITION

The general condition of the concrete specimen is provided in Table 3, the general view is shown in Figure 1.

Table 3 - Summary of the general condition of concrete specimen P13-14S

	Observation
Surface	Smooth, wide crack observed on the surface, top surface is finished with a sort of cement-based coating
Protective Coating	Cement-based surface finish
Paste	Soft across the sample, white in color, water absorption is high across the sample, moderate amounts of crystalline salts exuded after partial soaking sample in water
Cracks	Wide macro-crack along the core was observed and relatively infrequent micro-crack in the paste were found
Voids	Air content estimated at 3%, mostly small, round and entrapped voids are present. No deposits in the air voids was observed

PASTE

The microscopic investigation revealed the following features of the hardened cement paste matrix:

- The paste is soft (2-3 on the Mohs hardness scale) throughout the section of the core, suggesting that the concrete mixture has a high water-to-cement ratio. Overall hardness of the sample was similar to a lab reference concrete mixture made with 0.5-0.6 water-to-cement ratio.
- The hardened paste is uniform white in color in the bulk section of the core. However, in the top and bottom of the core veneer of paste is dark brown. In addition, it seems that the top surface of the core was coated with a sort of cement-based layer. Figure 2 shows examples of a brown cement-based primer on the surface of core P13-14S.
- The capillary porosity and rate of water sorption of the hardened paste were high. The amount of paste appears to be high for the investigated concrete and was estimated at approximately 30-33%.
- Moderate amount of crystalline deposits exuded on the surface of partially submerged sample. The crystals where white to transparent is color and appeared in the paste and paste-aggregate interface. Figure 3 shows examples of crystalline deposits exuded on the surface of core P13-14S.
- The specimen shows wide crack on the surface which extended longitudinally through the full length of the core. The macro-crack observe in the sample was free from deposits and ran

through paste and paste-aggregate interface. At a depth of 4 ¼” from the surface the macro-crack splits into two smaller cracks. Figure 4 shows longitudinal macro-cracks in sample 13-14S.

- The micro-cracks in the sample were relatively infrequent and were observed in the bulk section of the core. Most of the micro-cracks run in the paste and around aggregates, and are free from deposits. Figure 5 shows examples of micro-cracks in sample P13-14S.
- The air content in the hardened paste is low. The observed air voids are round and small in size. Based on the visual appearance of the air voids, it is concluded that the concrete was not intentionally air-entrained and the estimated air content is approximately 3%. The air voids are generally free from deposits as indicated in Figure 6.
- The carbonation was uniform and was measured through the entire cross-section of the core. Figure 7 shows lack of pink staining in the core sample.

COARSE AGGREGATE

- The coarse aggregate is a crushed stone with 19 mm (¾in.) nominal top size. The rocks are hard and many particles are cracked. The particles are sub-equant to elongate in shape with angular to sub-angular edges. The grading is uniform and the aggregate distribution is even.
- The aggregate is siliceous in composition and consists of a mixture of granite, diorite, quartzite, andesite and schist.
- The bond between the coarse aggregate and hardened paste is weak and frequently compromised by the presence of gaps.
- A few aggregate particles were cracked and exuded traces of alkali-silica gel on the surface and into micro-cracks. The signs of aggregate deterioration in the coarse aggregates are minor, but clearly indicate the potential for ASR in the investigated concrete. Figure 8 shows coarse particles which show signs of alkali-silica reactivity.

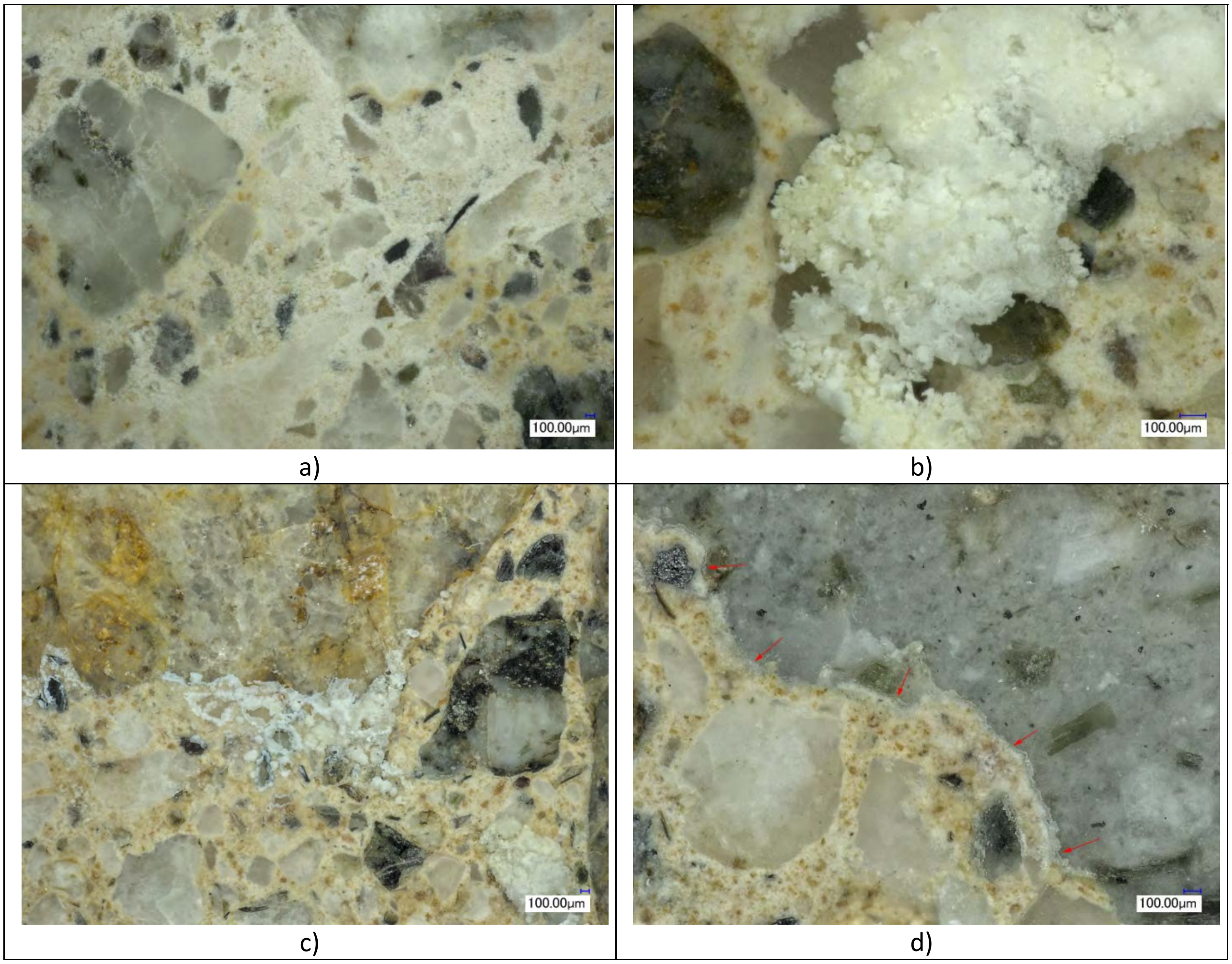
FINE AGGREGATE

- The fine aggregate is a siliceous sand. The major components present in the sand include: quartz, feldspar, andesite and rhyolite.
- A few ASR susceptible sand particles were found in core P13-14S. The majorities of the ASR susceptible particles have micro-cracks cutting through them, have reaction rims and amorphous gel deposited in the micro-cracks (see Figure 9).

Figure for sample P13-14S

Figure 1– Core P13-14S before cutting and lapping

Figure 2 – Brown cement-based coating on the surface of the core



a) b) c) d)

Figure 3 – Examples of crystalline salts exuded on the surface of lapped section of P13-14S: a,b) white crystals in paste and (c,d) crystals around coarse aggregate rocks

Figure 4 – Longitudinal macro-crack in the top portion of the core

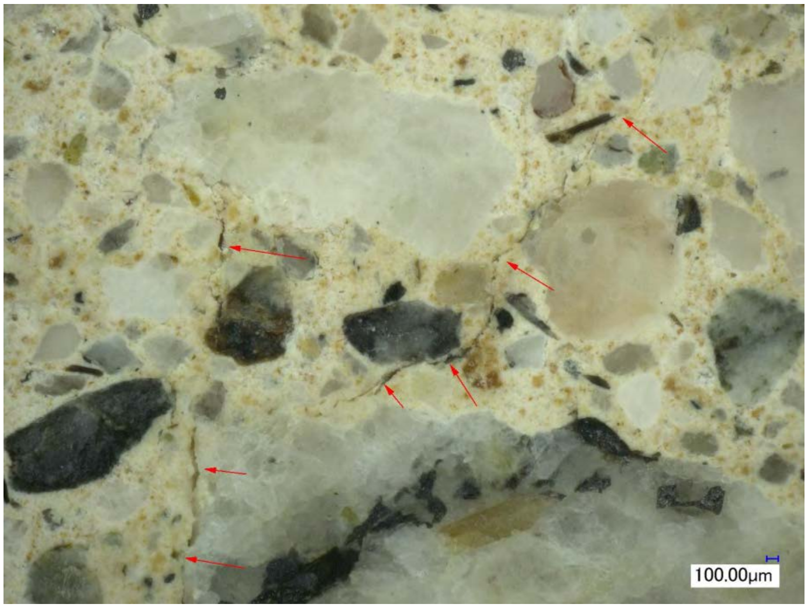


Figure 5 – Examples of micro-cracks in sample P13-14S

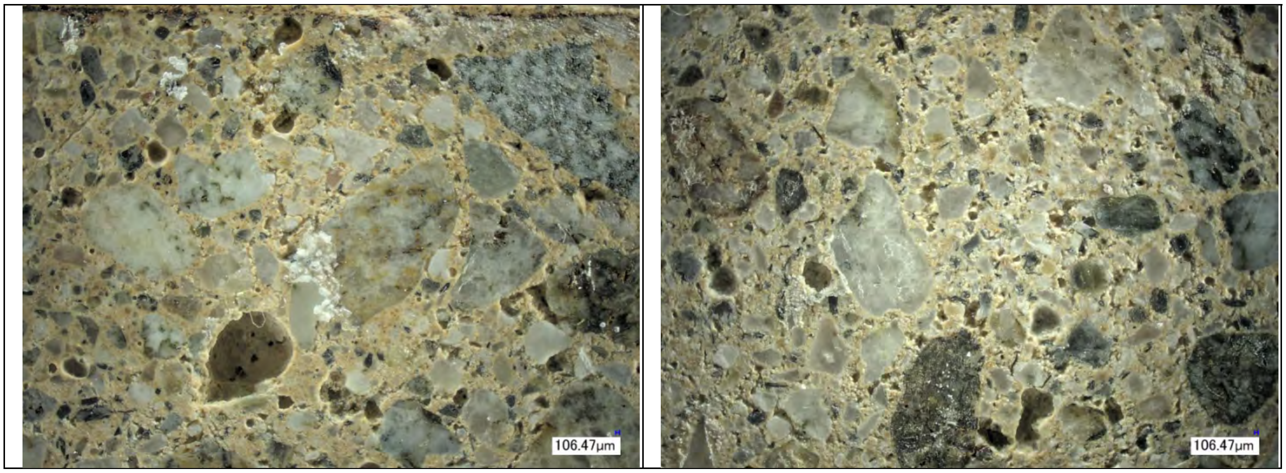
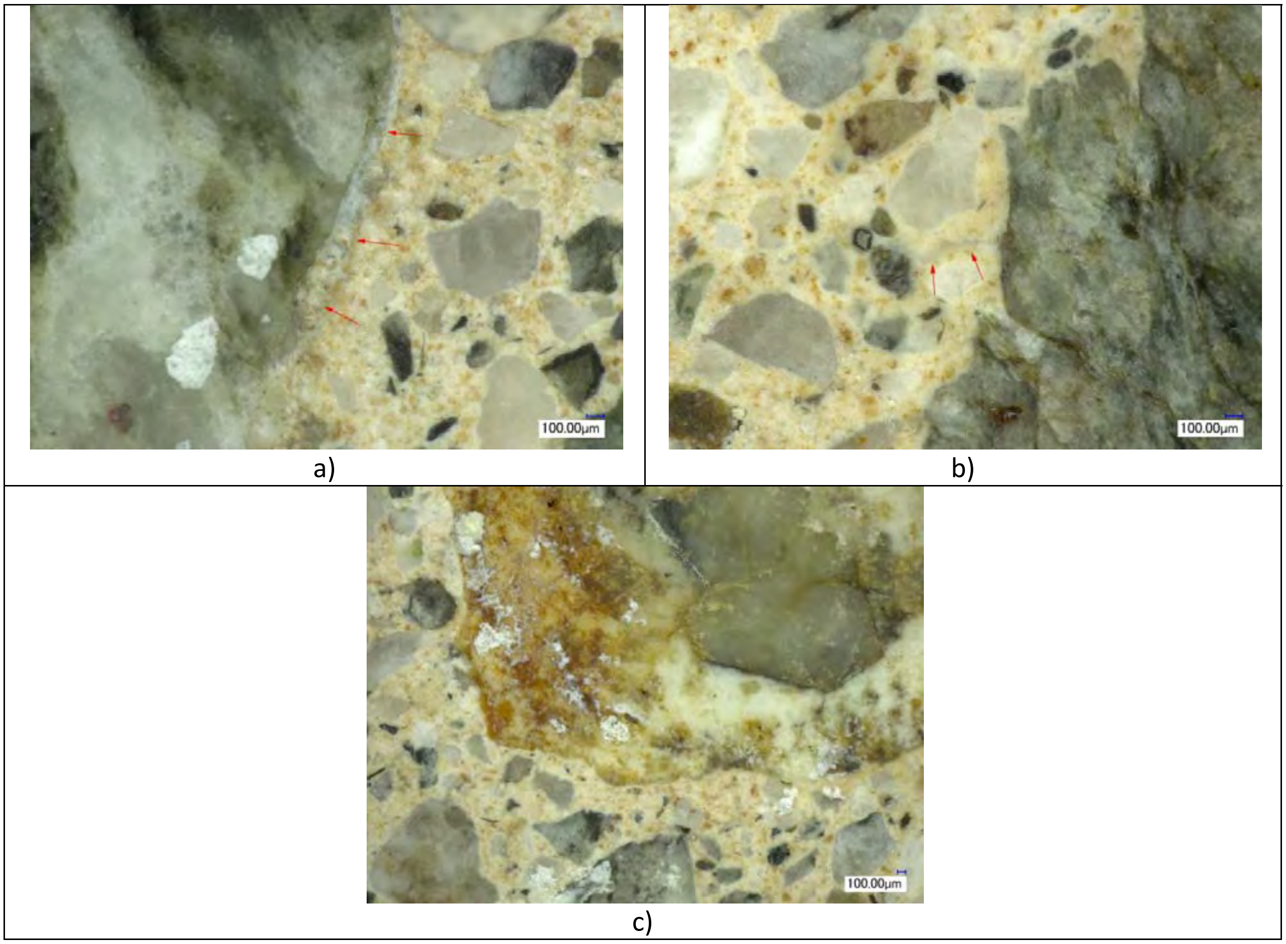


Figure 6 – Examples of air voids in core P13-14S

Figure 7 – Core P13-14S after staining with phenolphthalein showing lack of pink staining through the entire section of the core

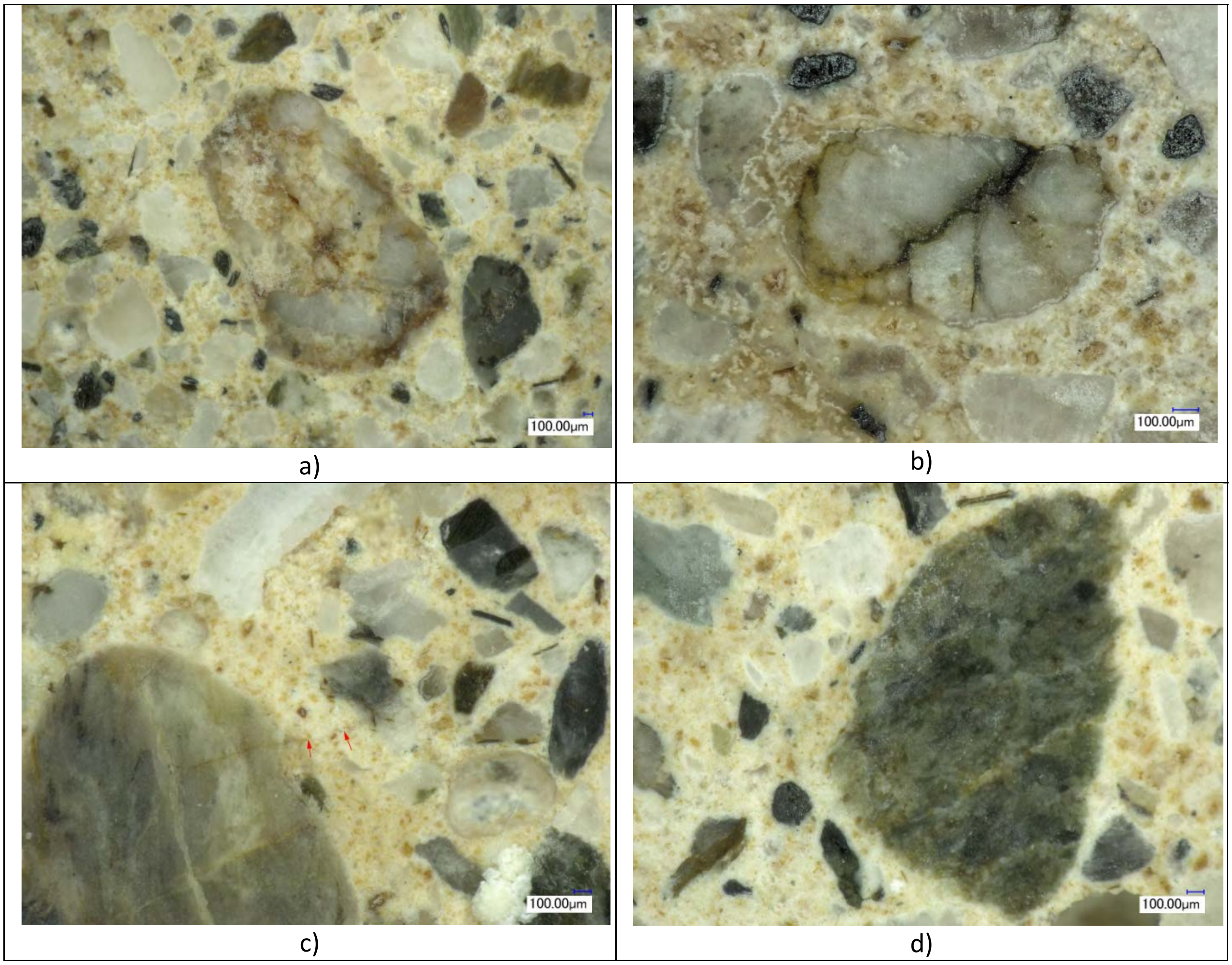


a)

b)

c)

Figure 8 – Examples of coarse particles with alkali-silica gel in core P13-14S: a) in gap around aggregate, b) in micro-crack near aggregate and c) exuded on the surface of coarse aggregate



a) b) c) d)

Figure 9 – ASR susceptible sand particles: a,b) with rims and (c,d) with micro-crack and traces of gel in core P13-14S

RESULTS OF PETROGRAPHIC EXAMINATION

Sample P19-20S

GENERAL CONDITION

The general condition of the concrete specimen is provided in Table 4, the general view is shown in Figure 10.

Table 4 - Summary of the general condition of concrete specimen P19-20S

	Observation
Surface	Smooth, the top 1 ¾” section of the core was fragmented, thus the real degree of cracking cannot be determined, top surface is finished with a sort of cement-based coating
Protective Coating	Cement-based surface finish
Paste	Soft across the sample, white in color, water absorption is high across the sample, high amounts of crystalline salts exuded after partial soaking sample in water
Cracks	Many macro-cracks were randomly spread in the bulk paste, the micro-cracking was infrequent and was found near reinforcing steel bar at a depth of 1 ¾” from the surface. Some of the micro-cracks near the rebar contain rust corrosion products
Voids	Air content estimated at 3%, mostly small, round and entrapped voids are present. The air voids contain small amounts of crystalline deposits

PASTE

The microscopic investigation revealed the following features of the hardened cement paste matrix:

- The paste is soft (2-3 on the Mohs hardness scale) throughout the section of the core, suggesting that the concrete mixture has a high water-to-cement ratio. Overall hardness of the sample was similar to a lab reference concrete mixture made with 0.5-0.6 water-to-cement ratio.
- The hardened paste is uniform white in color in the bulk section of the core. However, in the top and bottom of the core veneer of paste is dark brown. In addition, it seems that the top surface of the core was coated with a sort of cement-based layer. Figure 11 shows examples of a brown cement-based primer on the surface of core P19-20S.
- The capillary porosity and rate of water sorption of the hardened paste were high. The amount of paste appears to be high for the investigated concrete and was estimated at approximately 30-33%.
- High amount of crystalline deposits exuded on the surface of partially submerged sample. The crystals where white to transparent is color and appeared in the paste and paste-aggregate interface. Figure 12 shows general view of crystalline deposits exuded on the surface of core P13-14S, whereas Figure 13 shows detailed morphology of these crystals.

- The specimen shows wide-spread cracking in the bulk portion of the core. Due to extensive damage in the sample to origin of these cracks is not easy to determine. However, it can be observed that the macro-cracks run around the rebars and in the bulk paste between the rebars. The macro-cracks in the sample are free from deposits and ran through paste and paste-aggregate interface. Figure 14 shows macro-cracks in sample P19-20S.
- The micro-cracks in the observed sample were relatively infrequent and were mostly observed in the bulk section of the core near the reinforcing steel bars. Some of the micro-cracks run in the paste and are filled with rust crystalline deposits. Figure 15 shows examples of micro-cracks with rust corrosion products in sample P19-20S.
- The air content in the hardened paste is low. The observed air voids are round and small in size as indicated in Figure 16. Based on the visual appearance of the air voids, it is concluded that the concrete was not intentionally air-entrained and the estimated air content is approximately 3%. The air voids are generally free from deposits, however occasionally small amounts of crystalline salts were observed in voids (as shown in Figure 17).
- The carbonation was uniform and was measured through the entire cross-section of the core. Figure 18 shows lack of pink staining in the core sample.

COARSE AGGREGATE

- The coarse aggregate is a crushed stone with 25 mm (1 in.) nominal top size. The rocks are hard and many particles are cracked. The particles are sub-equant to elongate in shape with angular to sub-angular edges. The grading is uniform and the aggregate distribution is even.
- The aggregate is siliceous in composition and consists of a mixture of granite, diorite, quartzite, andesite and schist.
- The bond between the coarse aggregate and hardened paste is weak and frequently compromised by the presence of gaps.
- A few aggregate particles were cracked, but no signs of alkali-silica gel exuded on the surface these particles or in the surrounding cracks were found. The signs of aggregate deterioration in the coarse aggregates are minor, thus the potential for ASR in core P19-20S is negligible.

FINE AGGREGATE

- The fine aggregate is a siliceous sand. The major components present in the sand include: quartz, feldspar, andesite and rhyolite.
- A few ASR susceptible sand particles were found in core P19-20S. The majorities of the ASR susceptible particles have micro-cracks cutting through them, have reaction rims and amorphous gel deposited in the micro-cracks (see Figure 19).

Figure for sample P19-20S

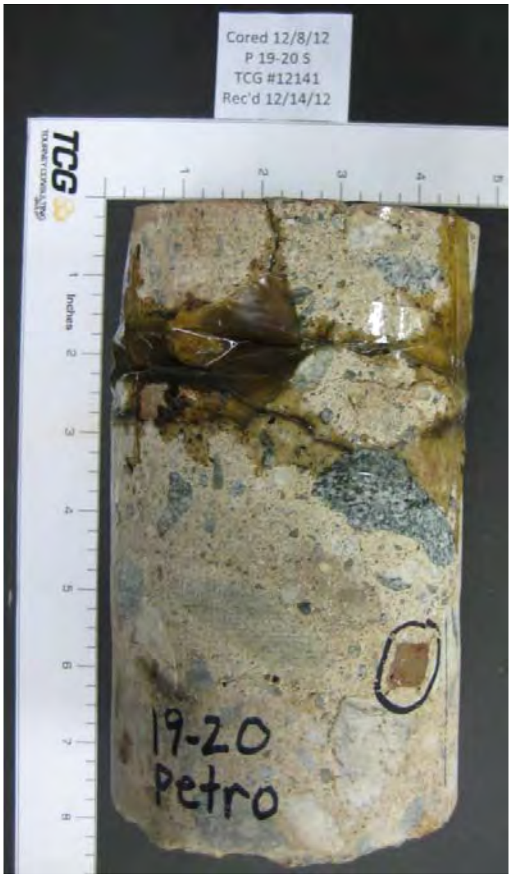


Figure 10– Core P19-20S before cutting and lapping

Figure 11 – Brown cement-based coating on the surface of the core

Figure 12 – Example of white crystalline deposits exuded on the surface of core P19-20S

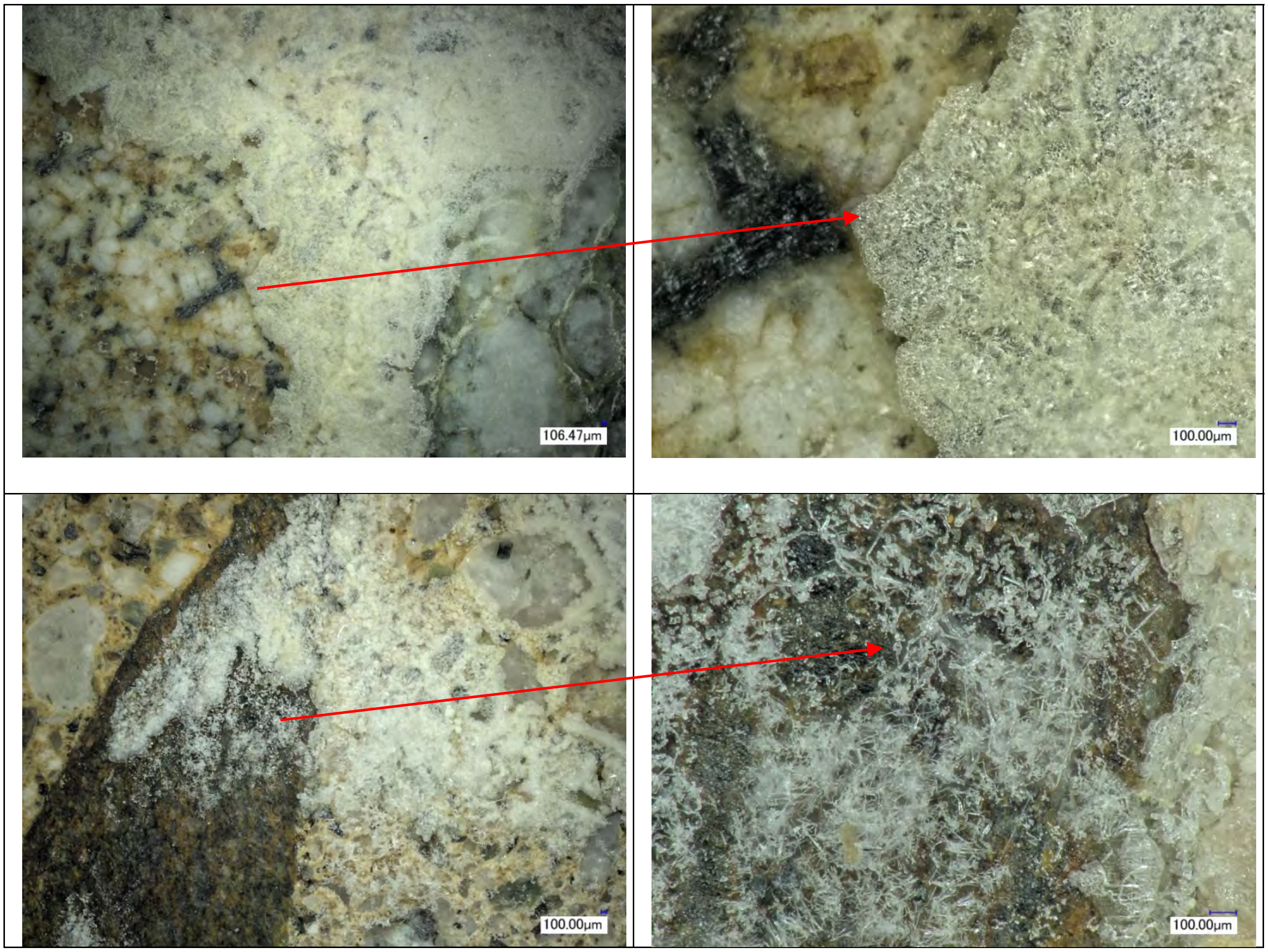


Figure 13 – Examples of microphotographs of crystalline salts exuded on the surface of lapped section of P19-20S sample

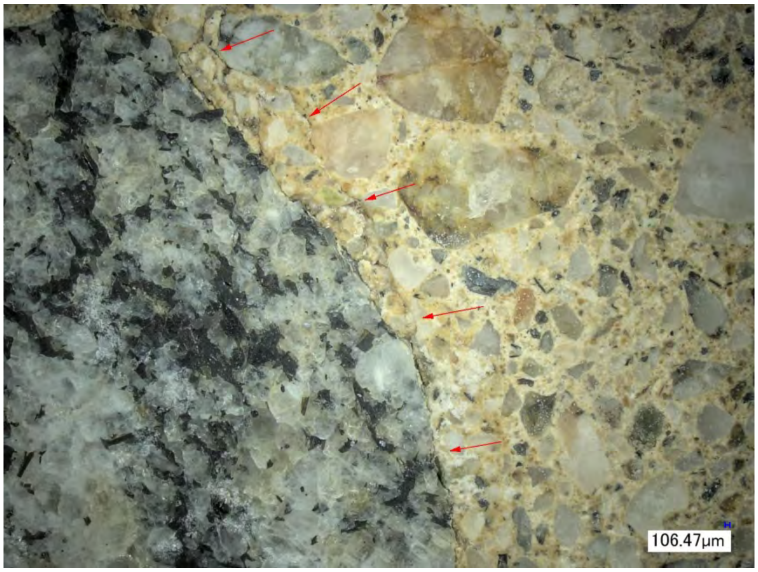


Figure 14 – Longitudinal macro-crack in the top portion of the core

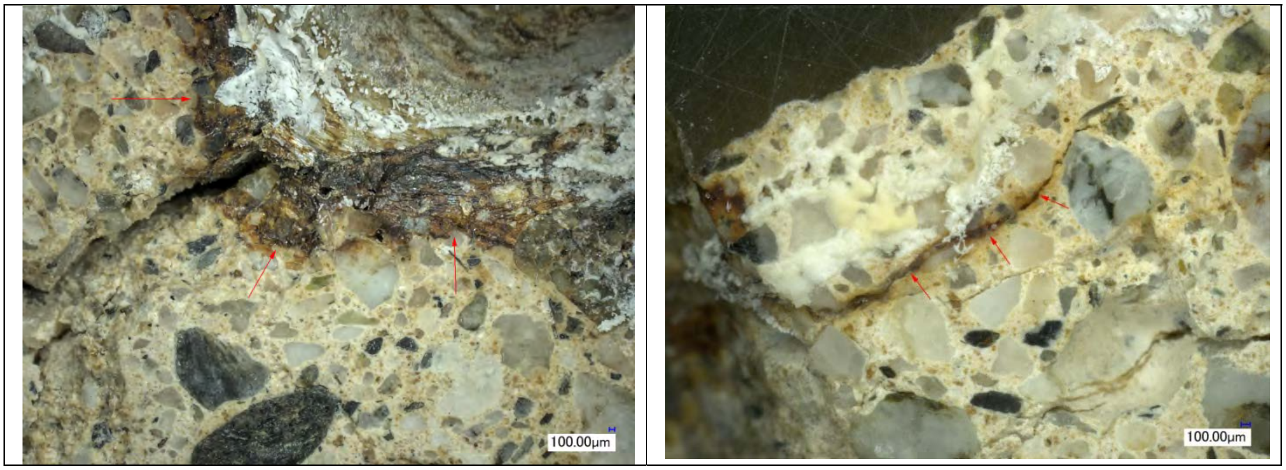


Figure 15 – Examples of micro-cracks with rust deposits in sample P19-20S

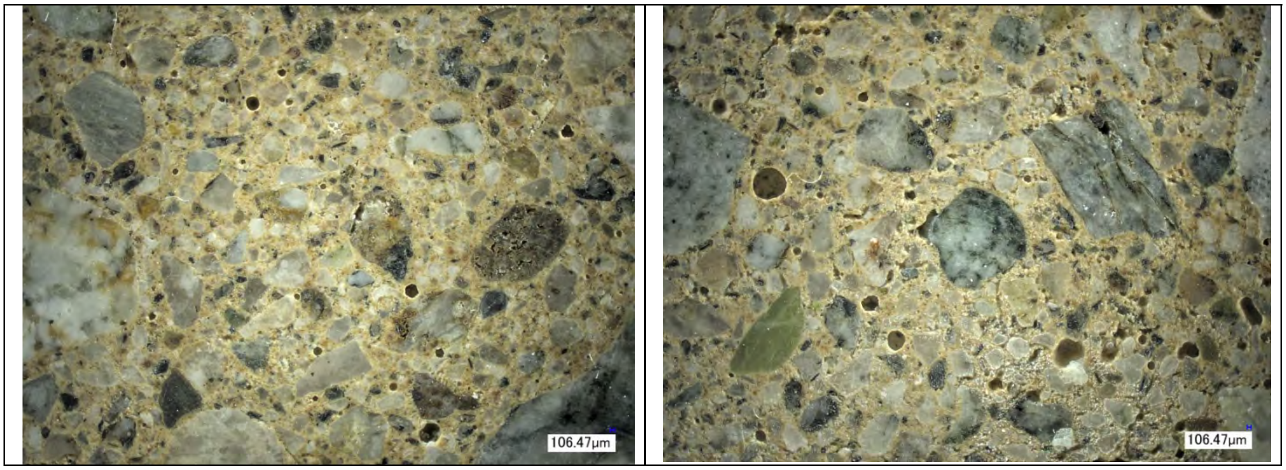
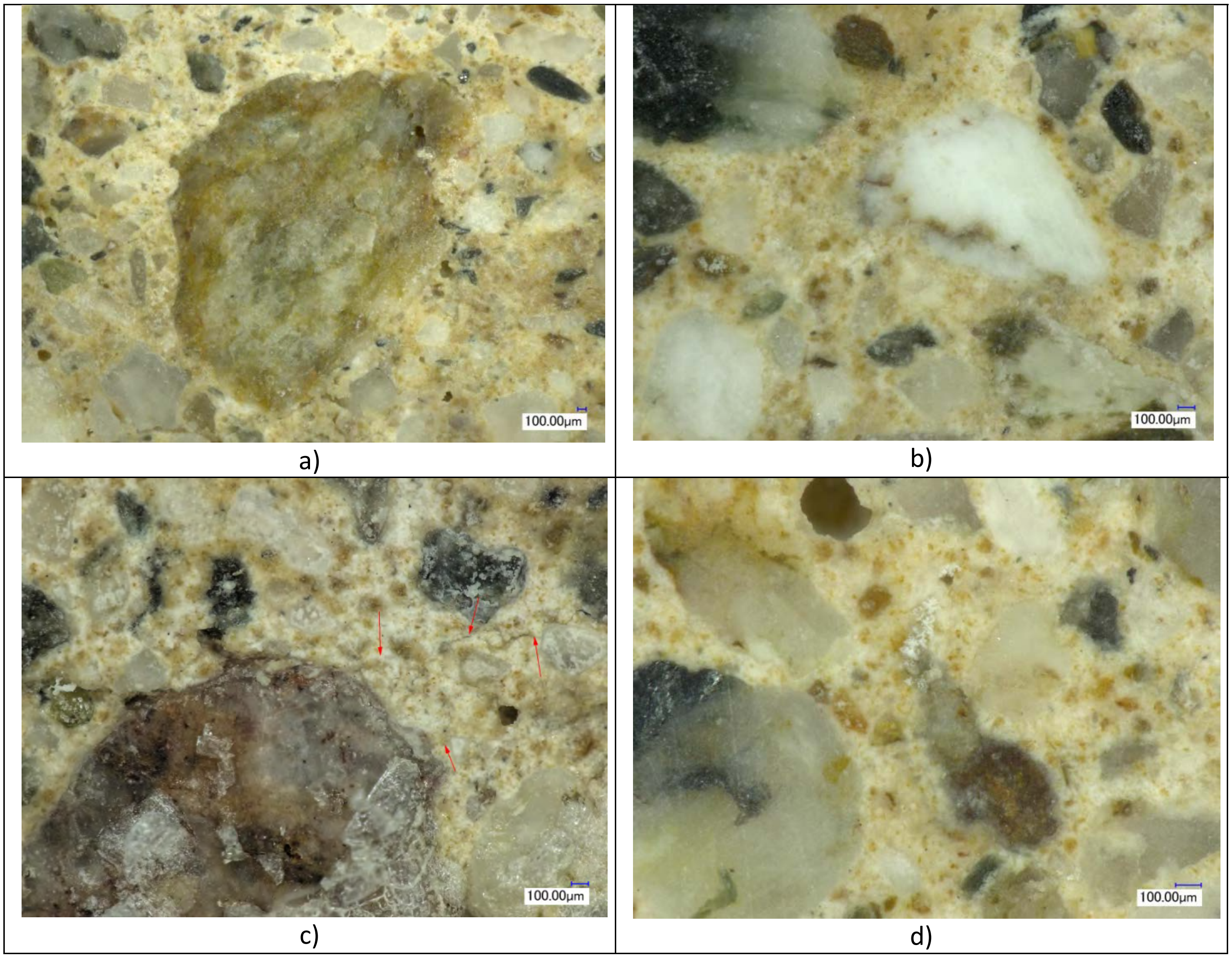


Figure 16 – Examples of air voids in core P19-20S

Figure 17 – Examples of crystalline deposits in void in sample P19-20S

Figure 18 – Core P19-20S after staining with phenolphthalein showing lack of pink staining through the entire section of the core



a) b) c) d)

Figure 19 – ASR susceptible sand particles: a,b) with rims and (c,d) with micro-crack and traces of gel in core P19-20S

Appendix D:

Photographs

Picture #1-Approximate 2.5” thick spall

Picture #2- Ceiling spall

Picture #3- Spall sprayed with rainbow indicator around a 6 pH

Picture #4- Soft concrete with small cracks in Section 11-12

Picture #5- Soft concrete and shallow spalls in Section 0-1

Picture #6- Water covering the tunnel floor in Section 12-13

Picture #7- Water covered floor and soft concrete with shallow spalls Section 12-13

Picture #8- Soft concrete Section 12-13

Picture #9- Soft Concrete Section 12-13

Picture #10- Soft concrete Section 12-13

Picture #11- Section 1-2 sounding survey

Picture #12- Soft concrete Section 3-4

Picture #13- Soft concrete Section 3-4

Picture #14- Efflourescent Section 3-4

Picture #15- Soft Concrete Section 3-4

Picture #16- Soft concrete Section 3-4

Picture #17- Soft concrete Section 3-4

Picture #18- Soft Concrete Section 3-4

Picture #19- Sounding survey Section 3-4

Picture #20- Soft Concrete Section 3-4

Picture #21- Soft concrete Section 5-6

Picture #22- Deteriorated joint near Station 6

Picture #23- Deteriorated joint near Station 6

Picture #24- Section 7-8

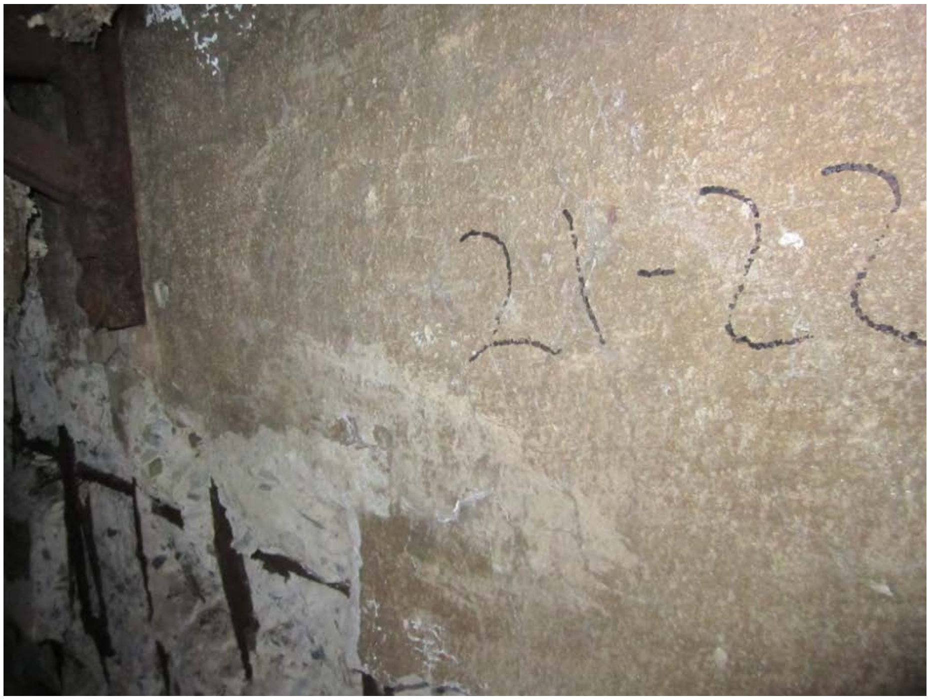
Picture #25- Ceiling spall Section 7-8

Picture #26- Damage from steam leak Section 8-9

Picture #27- Damage from steam leak Section 8-9

Picture #28- Soft concrete Section 15-16

Picture #29- Exposed reinforcing steel Section 15-16



Picture #30- Spall with exposed corroded reinforcing steel Section 21-22

Picture #31- Spall with exposed corroded reinforcing steel Section 21-22

Picture #32- Spall with exposed corroded reinforcing steel Section 21-22

Picture #33- Spall with corroded reinforcing steel at Station 25

Picture #34- Damage tunnel section with spalling and heavy corrosion near Station 26

Picture #35- Spall in Section 25-26 with broken reinforcing steel and extensive section loss

Picture #36- Ceiling delamination with corroded pipe, conduit, and reinforcing steel near Station 26

Picture #37- Delamination and severe reinforcing steel corrosion near Station 26

Picture #38- Deep spalling and extensive corrosion near Station 26

Picture #39- Delamination and spalling Section 35-36

Picture #40- Spalling and soft concrete Section 35-36

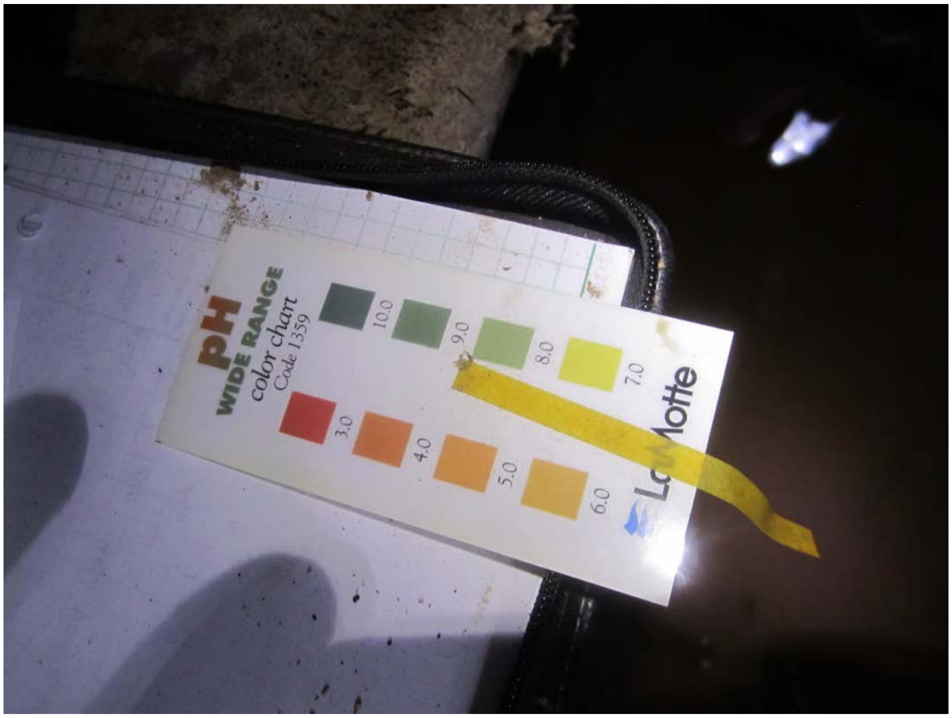
Picture #41- Spalling and soft concrete Section 35-36

Picture #42- Shallow delaminations Section 30-31

Picture #43- Spalling and corroded rebar Section 22-23

Picture #44- Spalling at Station 22

Picture #45- Spall with severe corrosion near station 22



Picture #46- pH test strip used to test standing water approximately a 7

Picture #47- Spacing of vertical reinforcement in Test Area 1

Picture #48- Spacing of horizontal reinforcement in Test Area 1

Picture #49- Exposed square Reinforcing bar 3/8"

Picture #50- Measurement of exposed reinforcing bar 3/8"

Picture #51- Spall near Station 19

Picture #52- Spall depth approximately 1-3/4" near Station 19

Picture #53- Spall next to leaking joint Section 19-20

Picture #54- Spalling near joint Section 19-20

Picture #55- Spalling Section 19-20

Picture #56- Ceiling spall Section 19-20

Picture #57- Severe spalling Section 20-21

Picture #58- Ceiling spall with broken corroded reinforcement steel Section 20-21

Picture #59- Spall with reinforcing steel with advanced corrosion occurring Section 20-21

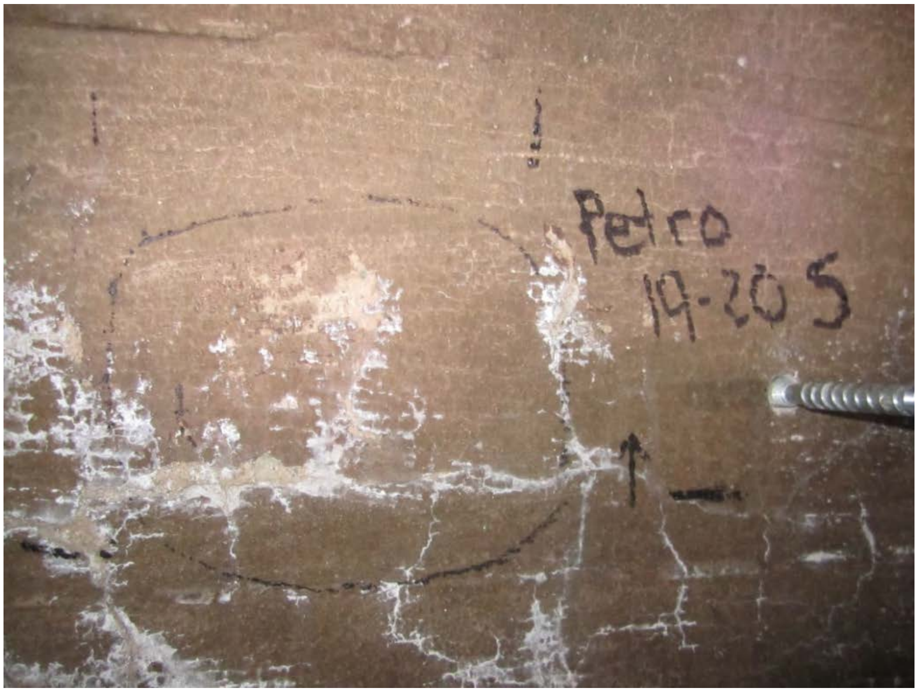
Picture #60- Spalling Section 20-21

Picture #61- Spalling Section 20-21

Picture #62- Compressive Strength core S19-20 on north wall

Picture #63- Core Hole from compressive strength core S19-20 on north wall approximately 5-3/8" thick

Picture #64- Compressive strength core S19-20 on north wall taken to full depth



Picture #65- Area of petrographic analysis core Petro19-20-S

Picture #66- Core hole for Petro19-20-S

Picture #67- Core Petro19-20-S

Picture #68- Core Petro19-20-S taken to full depth

Picture #69- Visible delaminated layer in core hole Petro19-20-S

Picture #70- Area of Core CS19-20-S

Picture #71- Core CS19-20-S

Picture #72- Core CS19-20-S taken to full depth approximately 6-1/4"

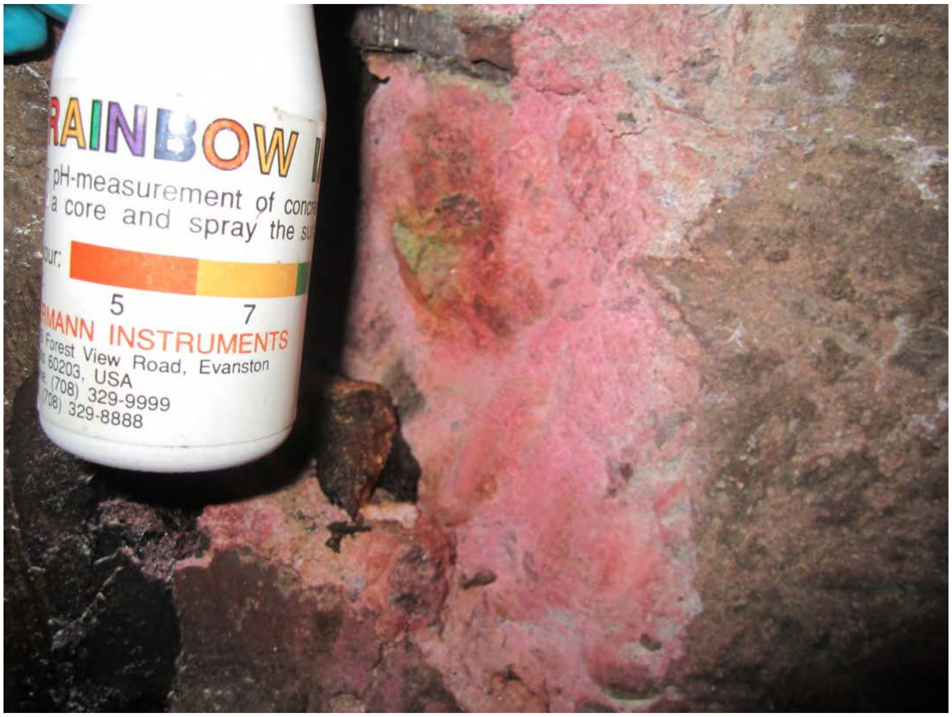
Picture #73- Area of core Petro13-14-S taken on a crack

Picture #74- Compressive Strength Core CS13-14S

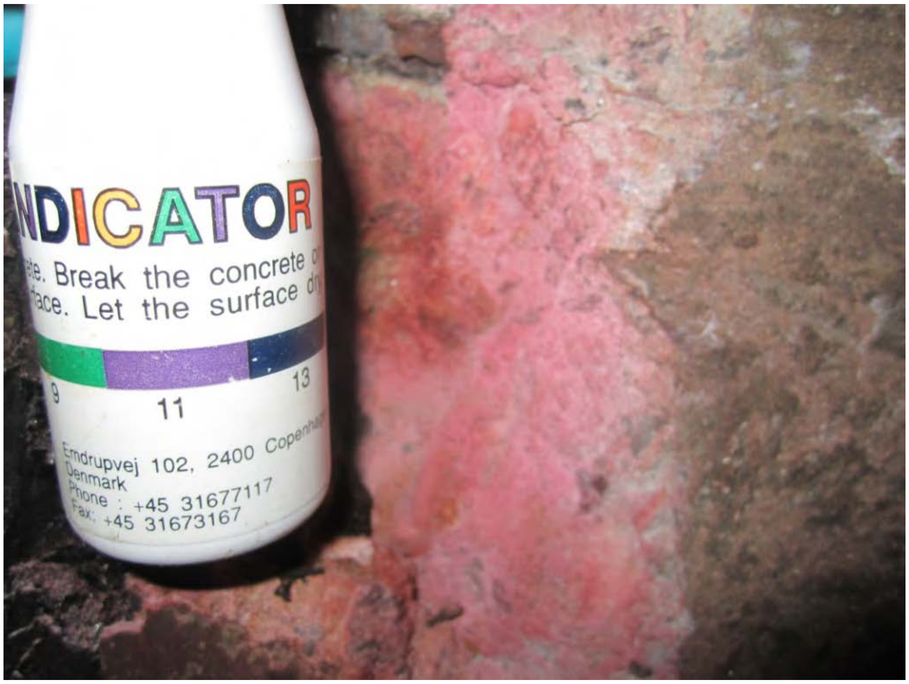
Picture #75- Core CS13-14S taken to full depth approximately 5-3/4" thick

Picture #76- Full depth core CS13-14N approximately 6" thick

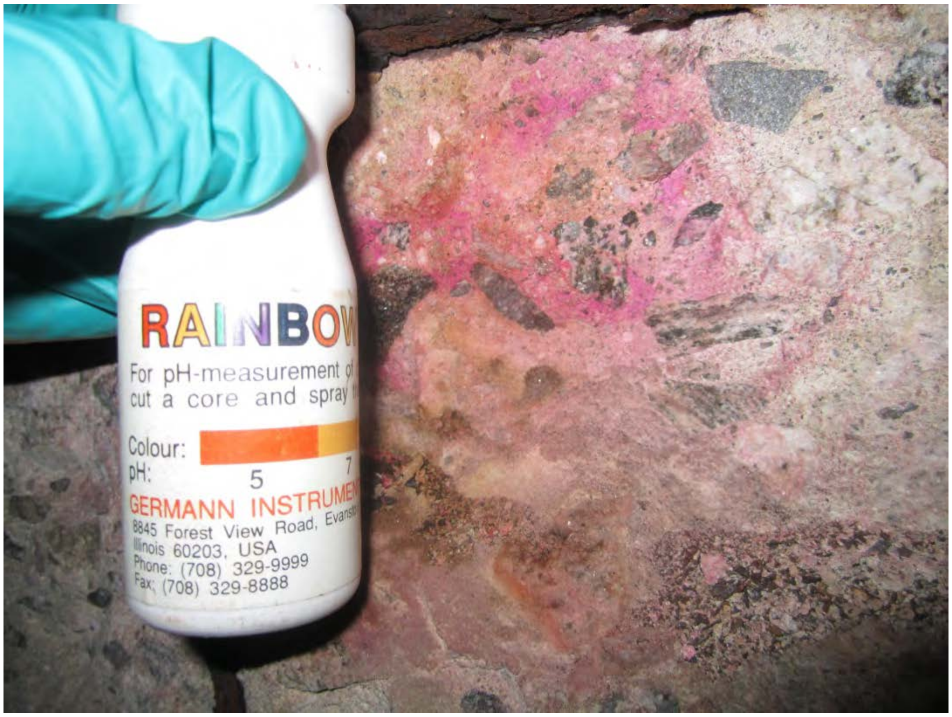
Picture #77- Petro13-14S visible crack



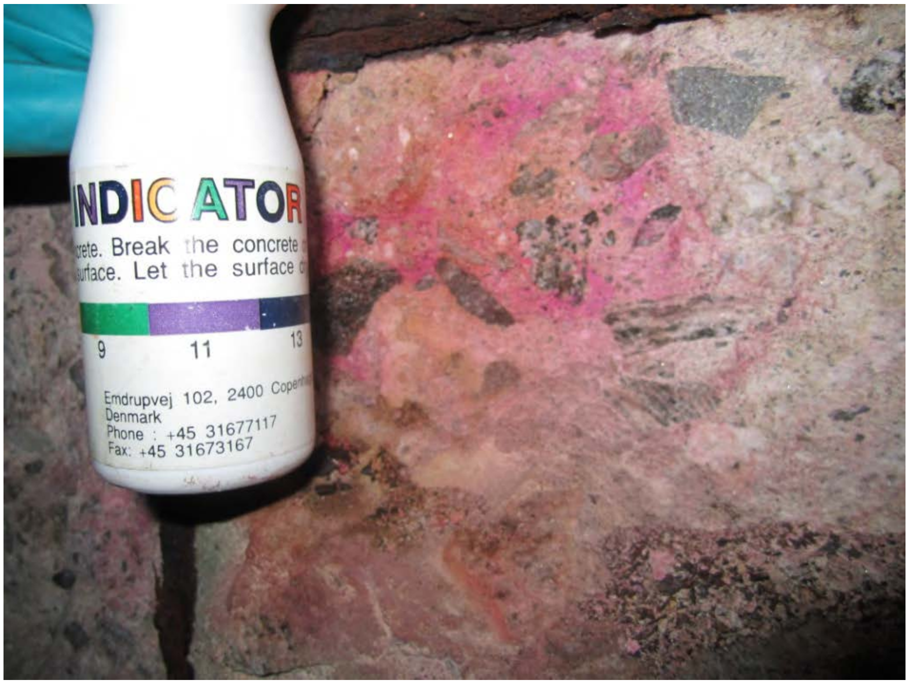
Picture #78- Spalled area indicating a PH of approximately 5



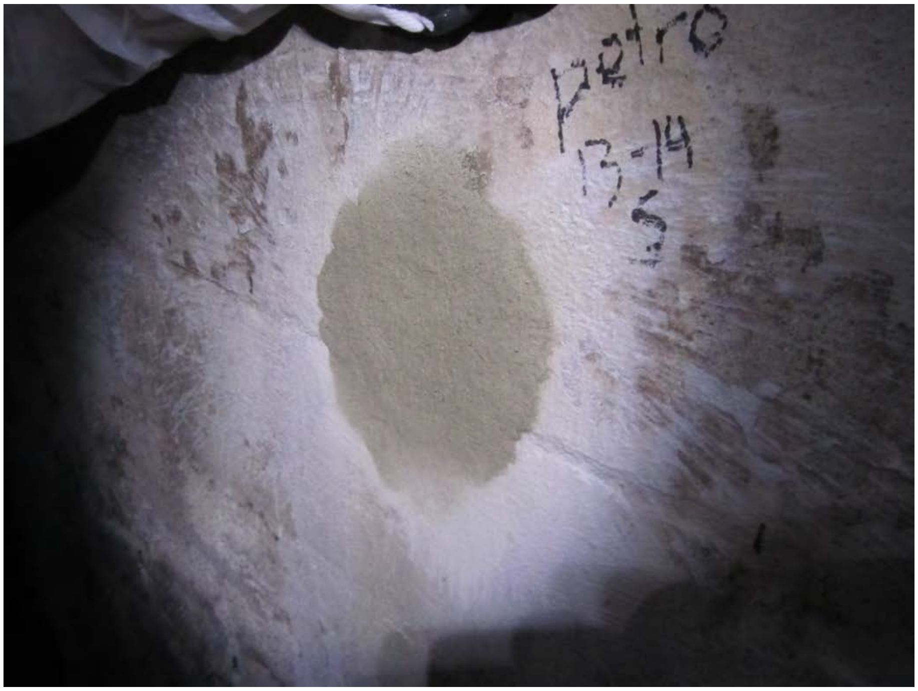
Picture #79- Spalled area indicating a pH of approximately 11



Picture #80- Spalled area indicating a pH of approximately 5



Picture #81- Spalled area indicating a pH of approximately 11

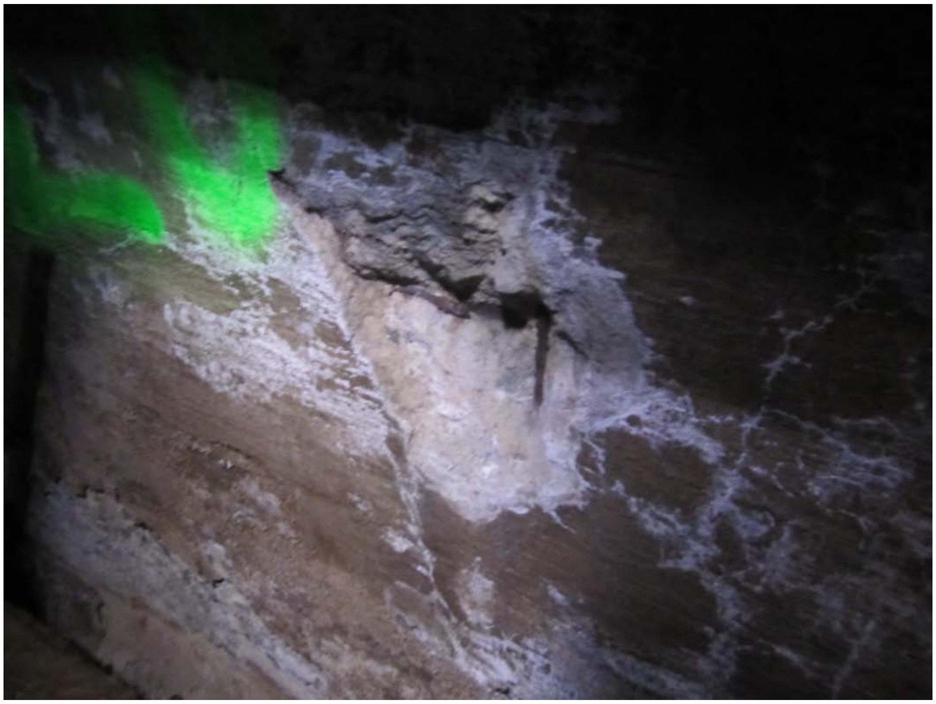


Picture #82- Patched core location

Picture #83- Spalling around a joint

Picture #84- Many small cracks

Picture #85- Soft flakey concrete



Picture #86- Spall around Station 20

Picture #87- Station 0

Picture #88- Steel does not cross joint

Picture #89- Steel lay-out Test Area 1

Picture #90- Corrosion potential testing in progress

Picture #91- Ceiling spall near Station 20

Picture #92- Ceiling Spall near Station 20

LAC + USC
Medical Center

TUNNEL EVALUATION REPORT

Los Angeles, California

January, 10, 2013

Submitted by

me engineers

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report was commissioned by the Los Angeles County Medical Center (LAC+USC) to assess the conditions of the existing steam piping in the utilities tunnel between Zonal Ave and Juvenile Hall (Parking Lot #71), and to provide recommendations.

The steam is being distributed from the existing Central Utility Plant (CUP) to provide steam throughout the campus. The steam piping in the studied utilities tunnel is supplying steam to the Juvenile Hall, ISD Blue Mill Building, and Raid Schneider Building.

The utilities tunnel consists of one steam supply pipe, two steam condensate return pipes and one electrical conduit, and they all appear to be in poor working condition. The steam supply and condensate return pipes are rusted and leaking; the insulations are torn and falling apart; and the steam supports are rusted. There are locations where the steam supports are not properly anchored to the concrete wall due to the concrete wall being delaminated. The electrical conduit is corroded.

Based on the Campus Master Plan, which is currently being developed, It is our understanding that the existing CUP will be replaced and the campus steam distribution will no longer be available. Since Juvenile Hall, ISD Blue Mill Building, Raid Schneider Building and other buildings (mainly office and laboratory buildings) do not require steam service in general, a central steam plant is not recommended. These buildings are mainly receiving steam from the existing central steam plant for space heating and domestic hot water. For better life cycle cost (energy, maintenance, and capital costs), our recommendation will be to use natural gas-fired high energy efficiency water boilers for space heating and water heaters for domestic hot water at each of these buildings. If there is any requirement for small steam usage for laboratory equipment such as sterilizers or kitchen cooking equipment, our recommendation will be localized electric steam generators be used for cost and energy effectiveness.
The following are the options to correct the piping deficiencies.

- Immediate Plan – Immediately repair the leaking piping and/or replace the insulation.
- Option #1 – Repair the tunnel, replace the steam pipes and insulation.
- Option #2 – Provide new pre-insulated underground steam pipes and bury the tunnel.
- Option #3 – Provide natural gas-fired high efficiency water boilers for space heating and water heaters for domestic hot water at each of these buildings; and local electric steam generators if required.

Depending on the project budget and timing, we recommend option #3.

I. INTRODUCTION

A. **Description**: According to the structural report, dated July 11, 2012, the South Side of the utility tunnel was originally constructed approximately in the 1930's and the North Side seems to be newer but could not be determined with the available documentation. The tunnel is in poor condition.

The utility tunnel consists of one steam supply pipe, two steam condensate return pipes and one electrical conduit. The steam is being distributed from the existing Central Utility Plant (CUP) to provide steam throughout the campus. The steam piping in the studied utilities tunnel is supplying steam to the Juvenile Hall, ISD Blue Mill Building and Raid Schneider Building.

B. **Objective**: The purpose of this report is to generally observe and evaluate the existing steam piping conditions with steam system "ON" AND "OFF"; to identify any apparent deficiencies and maintenance issues, and provide an assessment of the steam piping working condition and corrections, including our recommendations. M-E Engineers, Inc. (M-E) did not perform any testing to verify the existing steam pipe conditions.

M-E does not represent this document to be a finite accounting of all possible steam piping deficiencies or Code related issues facing the Hospital. The information contained in this report represents our best effort to identify and document such issues.

This report includes recommendations to correct the deficiencies in the system that have been identified as a result of this evaluation.

C. **Acknowledgement:** The interview conducted by M-E on December 9, 2012 was with Mr. Nester Miguel, Facility Engineer, and Mr. John Hill, Facility Engineer, and we wish to thank both of them for their assistance.

D. **Methodology**: M-E Engineers, Inc., as represented by Chris Dang performed a general observation of the steam piping system on December 9, 2012. A visual review of the steam piping system was performed, and an interview with Mr. Nester Miguel, Facilities Engineer and Mr. John Hill, Facilities Engineer, to gather information was conducted at that time.

The following is a listing of reference documents used in this review:

1. California Building Code (CBC), 2010 Edition
2. California Mechanical Code (CMC), 2010 Edition
3. California Plumbing Code (CPC), 2010 Edition
4. California Energy Code (Title 24), 2010 Edition

E. **Report Clarification**: The equipment condition terminology used throughout this report is explained as follows:

1. Good: The equipment is in top working condition. Usually, this category applies to new equipment that has recently been installed.

2. Fair: Equipment is in moderate working condition. This category applies to

equipment that has been in service for some time, having an acceptable performance level, but approaching the end of its useful service life expectancy. Equipment under this category is recommended to be replaced the next time it fails or requires major repair work.

3. Poor: Equipment is in undesirable working condition. This category applies to equipment with a high potential of failure, past its useful service life, and is in need of replacement. Equipment under this category is recommended to be replaced/repaired as soon as possible, depending on program planning and available funding.

II. OBSERVATIONS

The following are the results of our field observations for the steam piping and information provided by Mr. Miguel and Mr. Hill in our interview, and are intended to provide a summary of existing conditions and deficiencies.

A. Steam Piping:

1. Description: The steam is being distributed from the existing Central Utility Plant (CUP) to provide steam throughout the campus. The steam piping in the studied utilities tunnel is supplying steam to the Juvenile Hall's kitchen and provides building heat and domestic hot water for ISD Blue Building and Raid Schneider Building via a heat exchanger with the exception that steam is used to serve the existing space heaters (radiators) for space heating in the ISD Blue Building.

2. Safety Issues: There are a few safety issues at the locations, which we observed.

   a) Due to steam leaking and lack of insulation, it is extremely hot inside the tunnel which makes it unsafe to enter.

   b) Steam supports are rusted and not properly anchored or secured to the concrete which makes it unsafe to enter the tunnel with the steam system "ON".

3. Working Conditions: The steam supply and steam condensate return piping are black steel and in poor working condition; leaking steam and water in many locations (See Photos #1 thru 7). Steam piping are insulated with fiberglass on the South Side and insulated with asbestos (See Photo #8) on the North Side of the utility tunnel. The fiberglass insulation is in poor working condition and there is no insulation in many locations (See Photos #9 thru 11). Steam supports are rusted and not properly anchored or secured to the concrete wall due to the wall being spalled (See Photos #12 thru 14). The electrical conduit is completely corroded (See Photos #15 and 16).

   It was reported that there was no condensate return to the CUP.

III. DISCUSSIONS AND RECOMMENDATIONS

The following are discussions and recommendations of the steam piping system deficiencies to improve the system energy efficiency. An immediate plan and three option recommendations are presented in this section.

A. **System Deficiencies:** There are existing steam system deficiencies, which are as follows:

1. Steam piping: Steam piping has numerous leaks; maintenance and operating costs will be increasing.

2. Energy: The lack of insulation in the steam piping results in higher energy/operational cost.

3. Service and maintenance accessibility: It appears that the tunnel is extremely hot due to steam leaking. This presents a safety issue for the maintenance personnel.

4. In general, the steam piping is failing due to its age and lack of proper maintenance throughout the years.

B. **Recommendations:** We understand that there is a Campus Master Plan being developed. The decision for any major replacement and/or repair work of the existing system should be made with the understanding and consideration of the Campus Master Plan. It is improper to proceed with any replacement/repair plans independent of the Campus Master Plan.

Since our understanding of the Campus Master Plan is limited due to its early phase, the following are our recommendations to assist the Owner in making proper decisions for future planning.

The recommendations are based on an Immediate Plan and three options.

- Immediate Plan – Immediately repair the leaking piping and/or replace the piping.

- Option #1 – Repair the tunnel, replacet the steam pipes and insulation.

- Option #2 –Provide new pre-insulated underground steam pipes and bury the tunnel.

- Option #3 – Provide natural gas-fired high efficiency water boilers for space heating and water heaters for domestic hot water at each of these buildings; and local electric steam generators if required.

1. **Immediate Plan:**

- Steam piping: The existing steam piping serving Juvenile Hall, ISD Blue Mill Building and Raid Schneider Building are recommended to remain in the Immediate Plan. Under the Option #3, these three buildings are recommended to be decoupled from the existing Central Utility Plant. At that time, the existing piping can be abandoned in place.

- Piping insulation: New piping insulation is recommended to be installed to the existing piping and valves which have missing insulation.

2. **Options #1 to #3:**

The following table presents the Pros and Cons of these three options.

System	Pros	Cons
Option 1: Repair tunnel, replace steam pipes and replace insulation	Keep the tunnel	Highest capital cost Longer shutdown time for tunnel repair and replace steam piping.
Option 2: New pre-insulated underground steam pipes and bury tunnel	Keep the steam system	Disruption in the parking lot while installing underground steam piping
Option 3: New water boilers for space heating, new water heaters for domestic hot water	Better energy efficiency In line with the Master Plan	More equipment Replace existing space heaters (radiators) with heating hot water coils Natural gas pipe may be required at each building.

- From our professional experience and some obvious items listed in the Pros and Cons table above, Option 3 with new water boilers and water heaters is recommended because it provides better energy efficiency and is in line with the proposed master planning concept. We do not recommend Option 1 because it has the highest cost and will require major steam shut down time to repair the tunnel and re-install new steam pipes and cause disruption to the building operation.

C. **Benefits of Recommendations:** The recommendations presented above will resolve the existing issues for such as the steam leakages; as well as provide the following benefits:

1. Provide safe steam system.
2. Improve steam system energy cost.
3. Improve steam system maintenance cost.

ACKNOWLEDGMENTS

M-E Engineers, Inc. would like to thank the Los Angeles County Medical Center for giving us this opportunity to work with their organization to assess the steam distribution systems at the LAC+USC, and to give them our recommendations. It was a pleasure to work with an organization that is proactive about the quality and maintenance of their buildings' infrastructural equipment, as well as the care and well-being of their patient and workers.

APPENDICES

APPENDIX A

PHOTOS


PHOTO 1: STEAM CONDENSATE PIPE LEAKAGE


PHOTO 2: STEAM CONDENSATE PIPE LEAKAGE

PHOTO 3: STEAM CONDENSATE PIPE LEAKAGE AS IT HEADS TO JUVENILE HALL

PHOTO 4: STEAM PIPE LEAKAGE NEAR MANHOLE AT ZONAL AVENUE

PHOTO 5: TEAM PIPE LEAKAGE NEAR MANHOLE AT ZONAL AVENUE

PHOTO 6: STEAM ESCAPING (EASILY OBSERVABLE) THRU
EXHAUST FAN ON TOP OF MANHOLE AT ZONAL AVENUE

PHOTO 7: STEAM ESCAPING (EASILY OBSERVABLE) THRU EXHAUST FAN ON TOP OF MANHOLE AT ZONAL AVENUE

PHOTO 8: STEAM PIPE INSULATED WITH ASBESTOS


PHOTO 9: INSULATION IS FALLING APART


PHOTO 10: INSULATION IS FALLING APART

PHOTO 11: INSULATION MISSING FOR STEAM SUPPLY PIPE

PHOTO 12: STEAM SUPPORT NOT PROPERLY
ANCHORED OR SECURED TO CONCRETE WALL

PHOTO 13: CONCRETE WALL SPALLED

PHOTO 14: CONCRETE WALL FELL ON TOP OF STEAM CONDENSATE PIPE


PHTO 15: ELECTRICAL CONDUIT CORRODED


PHOTO 16: ELECTRICAL CONDUIT CORRODED

Limited Asbestos Survey Inspection Report

Project Site:
LAC+USC Tunnel
Zonal Ave./Mission Rd.
Los Angeles, CA

Prepared for:
Vanir Construction Management, Inc.
4540 Duckhorn Drive, Suite 300
Sacramento, CA 95834

Record of Certification:

This is to certify that this report was prepared by Focus Environmental Consulting, LLC (Focus) under contract with Vanir Construction Management, Inc. for the limited asbestos survey inspection conducted at the LAC+USC tunnel project located in Los Angeles, California. The inspection was completed utilizing applicable Federal and California State regulations. The findings in this report are consistent with accepted principles and practice established and prescribed by the EPA.

This report, the supporting data, findings, conclusions, opinions, and the recommendations it contains, represents the result of Focusôefforts on behalf of your firm. This report is not an abatement specification and should not be used for specifying removal methods or techniques.

The results, assessments and conclusions stated in this report are factually representative of the conditions and circumstances observed at this location on the dates of the inspection. We cannot assume responsibility for any change in conditions or circumstances that occurred after the inspection was completed.

Introduction:

Report Date:	December 17, 2012
Client:	Vanir Const. Mgmt., Inc. 4540 Duckhorn Dr., Suite 300 Sacramento, CA 95834
Project Site:	LAC+USC Tunnel Zonal Ave./Mission Rd. Los Angeles, CA
Scope of Work:	Limited Asbestos Survey
Project Date(s):	December 7, 2012

Summary:

The following is a report for the limited asbestos survey inspection conducted by Mr. Raed Sahawneh (CSST #09-2692) of Focus Environmental Consulting, LLC (Focus). The survey was performed on December 7, 2012 at the above mentioned project site.

Site Description:

The underground steam tunnel is located in the parking lot of the USC Medical School parking lot. The tunnel included in our scope of work runs north to south and is approximately 600 linear feet long.

The tunnel is consists of a concrete floors, walls and ceilings. No other building materials were found in the steam tunnel.

No other areas, materials or structures were included in the inspection during the site visit. This report is limited to only the areas and materials called out in this report. Other hazards may exist that were not included in the scope of this survey. If exposed, these hazards may require further sampling and proper removal and disposal by a certified contractor.

Scope of Work:

The survey was conducted to identify asbestos containing material (ACM) prior to a planned renovation project. Sampling was limited to accessible materials reasonably assumed would be impacted by potential renovation activities.

The Focus representative was informed of the future renovation plans. The Focus representative then collected necessary samples to satisfy requirements prior to starting any renovation or demolition of the materials in the project area(s).

The scope of the assessment was as follows:

- Assess the project area and generate a sampling scheme.
- Collect PACM bulk samples.
- Quantify sampled material.

- Photograph sampled materials.

- Sketch drawing of the structure and sampled locations.

- Generate a final written report of our findings which include analytical results.

Methods and Sampling Strategy:

Asbestos Bulk Sample Analysis and Results

Bulk samples of all homogeneous materials from identified areas containing suspect ACM were collected. A homogeneous material is defined as a surfacing material, thermal system insulation (TSI), asbestos-containing construction material or miscellaneous material that is uniform in use, color, texture and age of construction. Presumed ACM was also physically assessed for friability, condition and disturbance factors. Inaccessible suspect materials could be located between walls, in voids, or in other inaccessible areas.

Note: under EPA assessment criteria, if a single sample of a homogeneous material tests positive for asbestos, all homogeneous materials in that functional space are considered to be asbestos containing.

As materials were identified, bulk samples were placed into individual sampling bags. Each sample was given a discreet identification number and recorded on chain-of-custody forms.

All bulk samples were submitted and analyzed by LA Testing Laboratory (LA Testing). LA Testing is accredited by the National Institute of Standards and Technologyôs National Voluntary Laboratory Accreditation Program (NVLAP #200232-0). The lab reports #321220844 and 321220880 are attached.

Samples were analyzed using the PLM techniques in accordance with methodology approved by the U.S. Environmental Protection Agency (EPA). As set forth in the Code of Federal Regulations, 40 CFR Part 763, Appendix A to Subpart F, Section 1.2 an 1.7.2.4, the lower limit of reliability detection for asbestos using the PLM method is approximately one percent (1%) by volume. Cal-OSHA defines asbestos containing construction materials (ACCM) as those materials having an asbestos content of greater than one tenth of one percent (>0.1%).

When None Detected (ND) appears in this report, it should be interpreted as meaning no asbestos was observed in the sample material above the reliable limit of detection for the PLM method.

A total of fourteen (14) suspect asbestos containing material bulk samples were identified and collected for analysis during the survey. Regulations require that any time ACMôs are impacted during repair, renovation, removal or demolition that the work be performed by properly trained and certified workers. The analytical findings are listed below:

Asbestos Containing Material(s)

Sample No.	Material Color & Description	Sample Location	Asbestos Result	Friable/Non-Friable	Quantity Condition
02, 03, 04	Black Wall Joint Sealant	Tunnel @ Northwest, North and Southwest Walls	5% Chrysotile	Non-Friable	7 L.F. (80 joints) Damaged
10, 11	TSI Pipe Insulation	Tunnel @ Large 12òPipe at North End	15% Amosite 3% Chrysotile	Friable	Fair
12, 13, 14	TSI Pipe Insulation	Tunnel @ Large 4òPipe at North End	15% Amosite 3% Chrysotile	Friable	Fair

Non-Asbestos Containing Material(s)

Sample No.	Material Color & Description	Sample Location	Asbestos Result	Friable/Non-Friable	Quantity Condition
01	TSI Pipe Elbows	Tunnel @ Center Manhole	ND	Friable	1 Elbow Damaged
05, 06, 07, 08, 09	Concrete Skim Coat	Tunnel @ Northeast, Center West, Southeast, Southwest Walls and Center Ceiling	ND	Friable	Damaged

ND = None Detected

Conclusions:

The interpretation of the preliminary findings identified in the submitted report is based upon the analytical findings, our professional experience and qualifications. The field investigation and laboratory results are limited to only those areas, which were exposed and/or physically accessible to the inspector as outlined by the scope of work. The report findings are also limited to the information obtained by the client at the time of inspection.

Focus does not take responsibility for exact footage of existing material at the project site. Quantities listed within this report are estimations only and should be confirmed by an abatement contractor prior to any renovation and/or demolition work being performed.

Limitations:

The data and observations collected during the course of the inspection have been gathered to provide the client with information pertaining to the areas of the subject property identified in this report. Although Focus believes that the findings and conclusions provided in this report are reasonable, the inspection is limited to the conditions observed and to the information available at the time of the inspection. Due to the nature of the work, there is a possibility that conditions may exist which could not be identified within the scope of the inspection or which were not apparent at the time of our site work. The inspection is also limited to information available from the client at the time it was conducted. It is also possible that the testing methods employed at the time of the report may later be superseded by other methods. Focus Environmental does not accept responsibility for changes in the state of the art.

We appreciate the opportunity in doing business with your firm. Should you have any further questions or concerns regarding this inspection and/or report, feel free to contact our office at (951) 545-2495.

Sincerely,
Focus Environmental Consulting, LLC

David Camarillo, Vice President
Certified Site Surveillance Tech. #98-2424

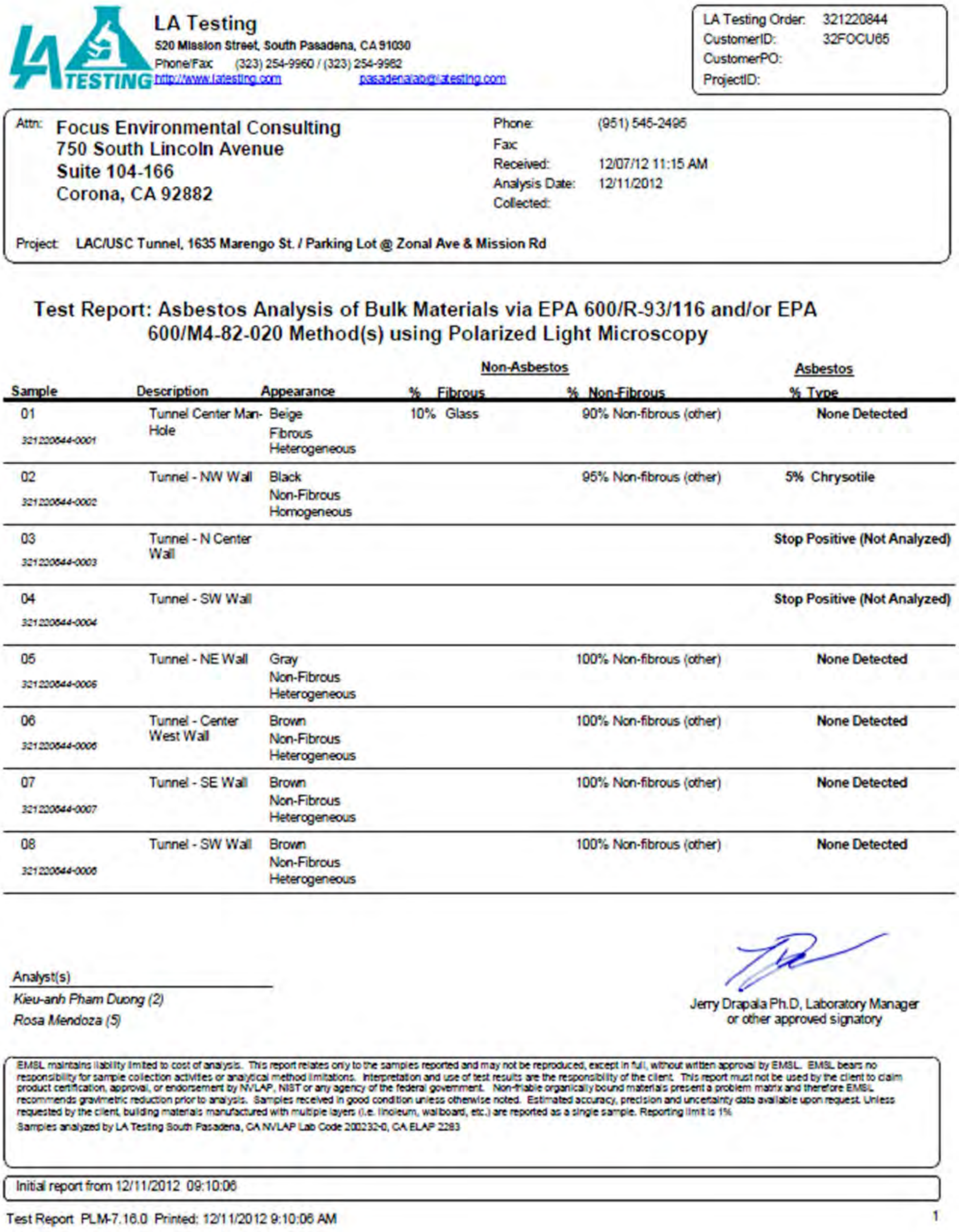
Rodica Dullabaun, Quality Control
Certified Asbestos Consultant #11-4716

Attachments:

Project Photographs
Laboratory Analytical Results/Sample Chains of Custody
Sample Location Sketches
InspectorsôAsbestos Certifications

Project Photographs

Laboratory Analytical Results/Sample Chains of Custody



LA Testing
520 Mission Street, South Pasadena, CA 91030
Phone/Fax: (323) 254-9960 / (323) 254-9982
http://www.latesting.com pasadenalab@latesting.com

LA Testing Order:	321220844
CustomerID:	32FOCU65
CustomerPO:	
ProjectID:	

Attn: **Focus Environmental Consulting**
750 South Lincoln Avenue
Suite 104-166
Corona, CA 92882

Phone:	(951) 545-2495
Fax:	
Received:	12/07/12 11:15 AM
Analysis Date:	12/11/2012
Collected:	

Project: **LAC/USC Tunnel, 1635 Marengo St. / Parking Lot @ Zonal Ave & Mission Rd**

Test Report: Asbestos Analysis of Bulk Materials via EPA 600/R-93/116 and/or EPA 600/M4-82-020 Method(s) using Polarized Light Microscopy

			Non-Asbestos				Asbestos	
Sample	**Description**	**Appearance**	**%**	**Fibrous**	**%**	**Non-Fibrous**	**%**	**Type**
01 321220844-0001	Tunnel Center Man-Hole	Beige Fibrous Heterogeneous	10%	Glass	90%	Non-fibrous (other)		**None Detected**
02 321220844-0002	Tunnel - NW Wall	Black Non-Fibrous Homogeneous			95%	Non-fibrous (other)	**5%**	**Chrysotile**
03 321220844-0003	Tunnel - N Center Wall							**Stop Positive (Not Analyzed)**
04 321220844-0004	Tunnel - SW Wall							**Stop Positive (Not Analyzed)**
05 321220844-0005	Tunnel - NE Wall	Gray Non-Fibrous Heterogeneous			100%	Non-fibrous (other)		**None Detected**
06 321220844-0006	Tunnel - Center West Wall	Brown Non-Fibrous Heterogeneous			100%	Non-fibrous (other)		**None Detected**
07 321220844-0007	Tunnel - SE Wall	Brown Non-Fibrous Heterogeneous			100%	Non-fibrous (other)		**None Detected**
08 321220844-0008	Tunnel - SW Wall	Brown Non-Fibrous Heterogeneous			100%	Non-fibrous (other)		**None Detected**

Analyst(s)
Kieu-anh Pham Duong (2)
Rosa Mendoza (5)

Jerry Drapala Ph.D, Laboratory Manager
or other approved signatory

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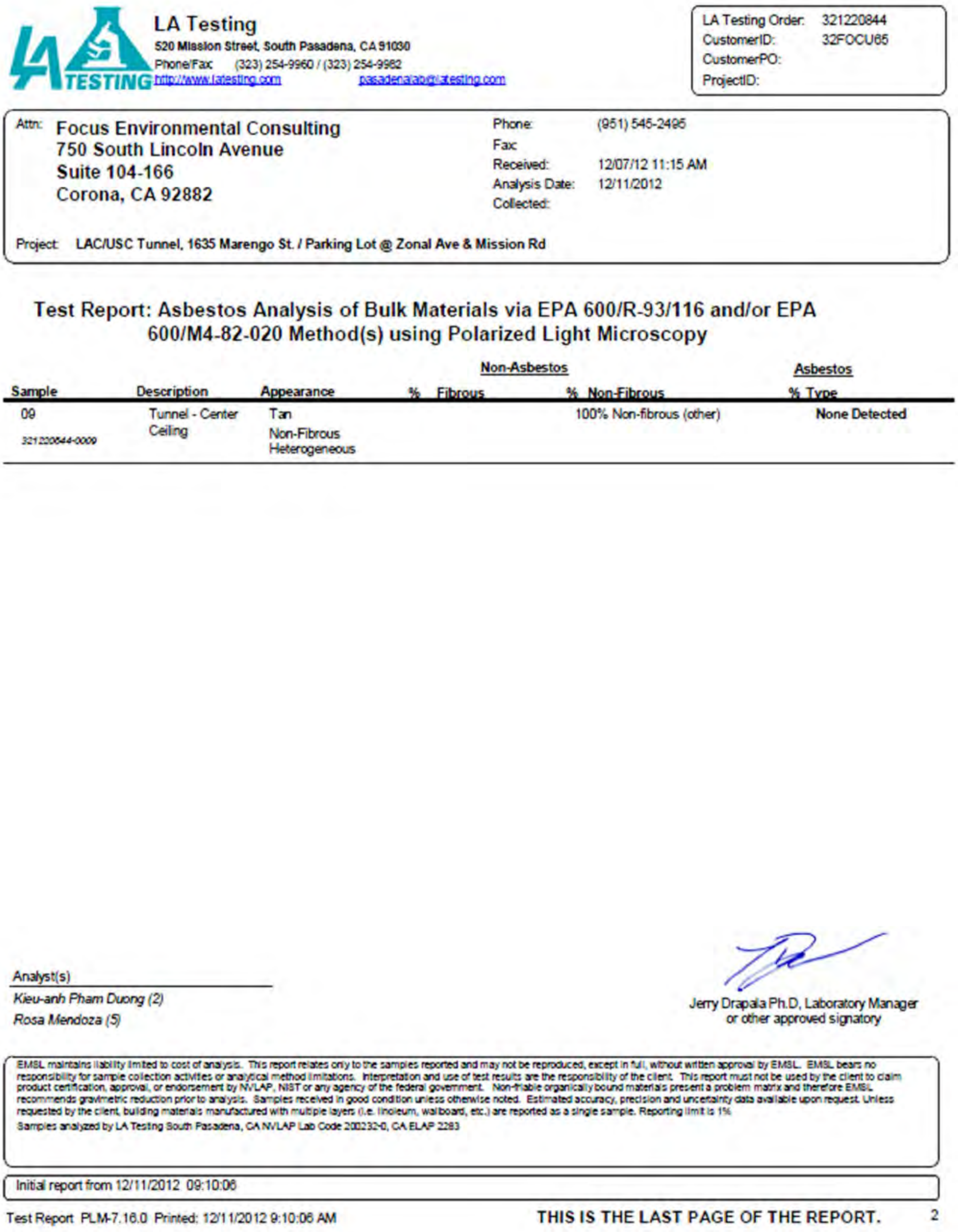
Samples analyzed by LA Testing South Pasadena, CA NVLAP Lab Code 200232-0, CA ELAP 2283

Initial report from 12/11/2012 09:10:06

Test Report PLM-7.16.0 Printed: 12/11/2012 9:10:06 AM 1

Laboratory Analytical Results/Sample Chains of Custody



LA Testing
520 Mission Street, South Pasadena, CA 91030
Phone/Fax: (323) 254-9960 / (323) 254-9982
http://www.latesting.com pasadenalab@latesting.com

LA Testing Order: 321220844
CustomerID: 32FOCU65
CustomerPO:
ProjectID:

Attn: Focus Environmental Consulting
750 South Lincoln Avenue
Suite 104-166
Corona, CA 92882

Phone: (951) 545-2495
Fax:
Received: 12/07/12 11:15 AM
Analysis Date: 12/11/2012
Collected:

Project: LAC/USC Tunnel, 1635 Marengo St. / Parking Lot @ Zonal Ave & Mission Rd

Test Report: Asbestos Analysis of Bulk Materials via EPA 600/R-93/116 and/or EPA 600/M4-82-020 Method(s) using Polarized Light Microscopy

			Non-Asbestos		Asbestos
Sample	Description	Appearance	% Fibrous	% Non-Fibrous	% Type
09 321220844-0009	Tunnel - Center Ceiling	Tan Non-Fibrous Heterogeneous		100% Non-fibrous (other)	None Detected

Analyst(s)
Kieu-anh Pham Duong (2)
Rosa Mendoza (5)

Jerry Drapala Ph.D, Laboratory Manager
or other approved signatory

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Samples analyzed by LA Testing South Pasadena, CA NVLAP Lab Code 200232-0, CA ELAP 2283

Initial report from 12/11/2012 09:10:06

Test Report PLM-7.16.0 Printed: 12/11/2012 9:10:06 AM

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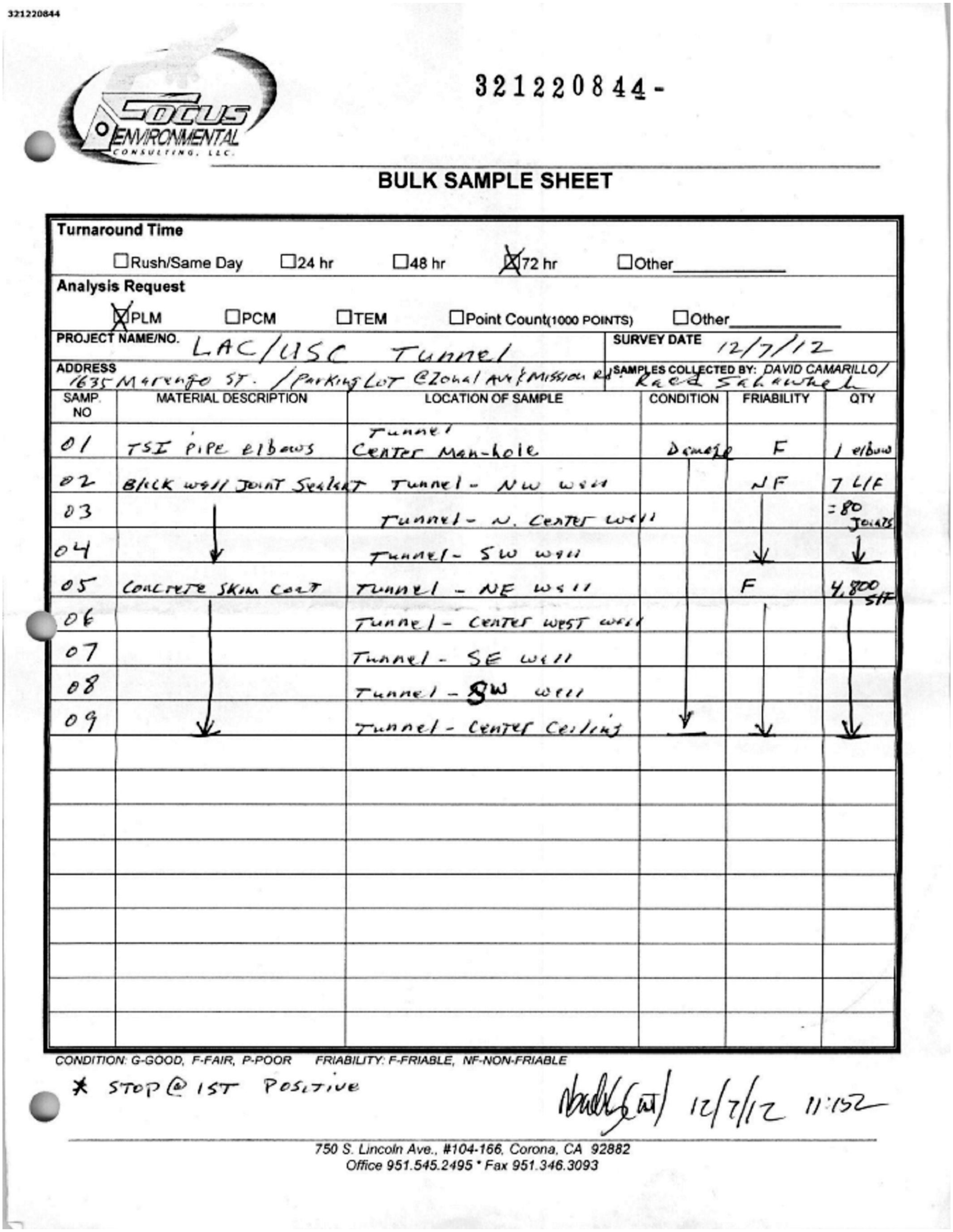
Laboratory Analytical Results/Sample Chains of Custody



321220844

FOCUS ENVIRONMENTAL CONSULTING, LLC

321220844-

BULK SAMPLE SHEET

Turnaround Time

☐Rush/Same Day ☐24 hr ☐48 hr ☒72 hr ☐Other________

Analysis Request

☒PLM ☐PCM ☐TEM ☐Point Count(1000 POINTS) ☐Other________

PROJECT NAME/NO. LAC/USC Tunnel

SURVEY DATE 12/7/12

ADDRESS 1635 Marengo St. / Parking Lot @ Zonal Ave & Mission Rd.

SAMPLES COLLECTED BY: DAVID CAMARILLO/ Raed Salawhel

SAMP. NO	MATERIAL DESCRIPTION	LOCATION OF SAMPLE	CONDITION	FRIABILITY	QTY
01	TSI pipe elbows	Tunnel Center Man-hole	Damage	F	1 elbow
02	Black wall Joint Sealant	Tunnel - NW wall	↓	NF	7 L/F
03	↓	Tunnel - N. Center wall	↓	↓	=80 Joints
04	↓	Tunnel - SW wall	↓	↓	↓
05	Concrete Skim Coat	Tunnel - NE wall	↓	F	4,800 S/F
06	↓	Tunnel - Center West wall	↓	↓	↓
07	↓	Tunnel - SE wall	↓	↓	↓
08	↓	Tunnel - SW well	↓	↓	↓
09	↓	Tunnel - Center Ceiling	↓	↓	↓

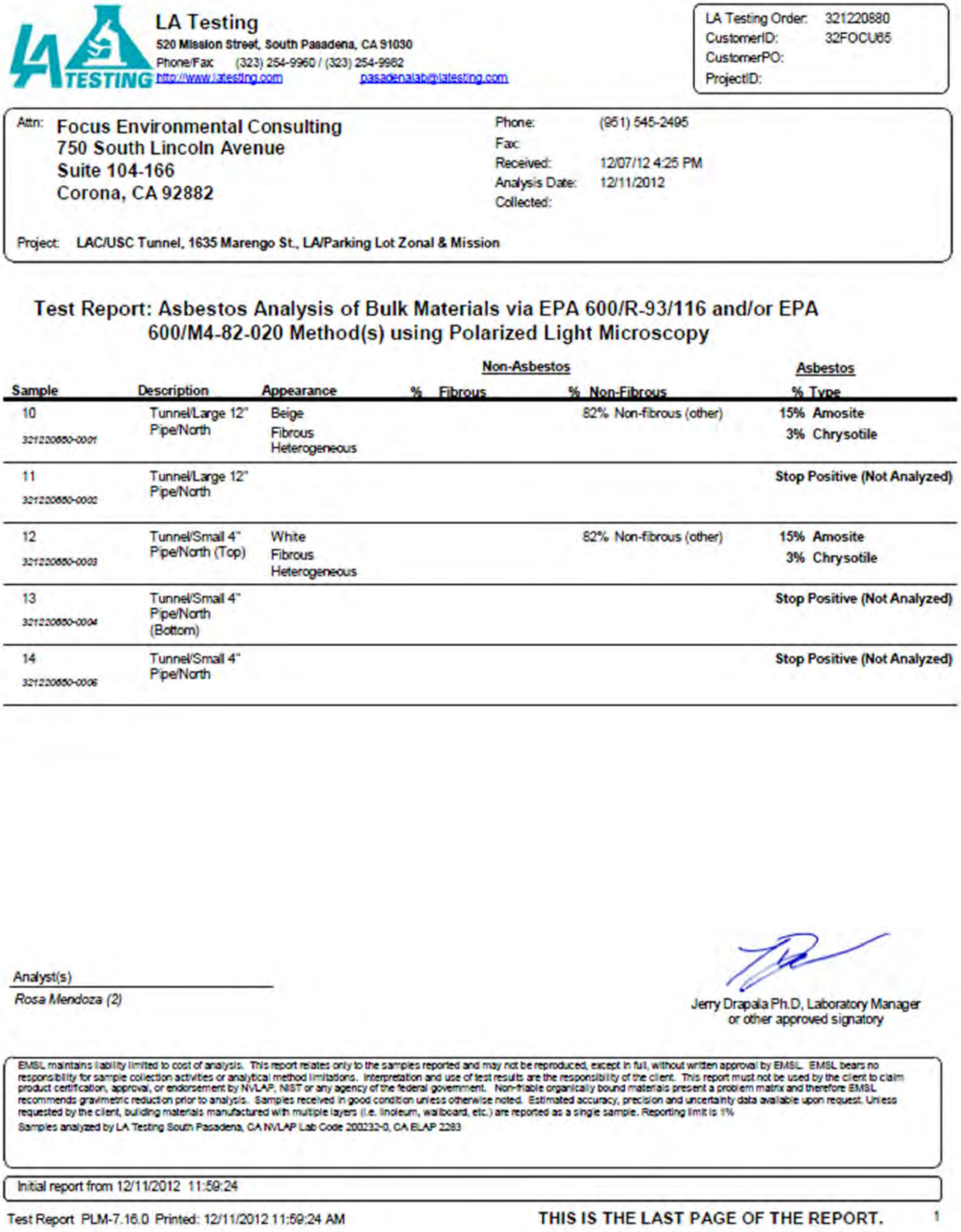
CONDITION: G-GOOD, F-FAIR, P-POOR FRIABILITY: F-FRIABLE, NF-NON-FRIABLE

* Stop @ 1st Positive

12/7/12 11:15

750 S. Lincoln Ave., #104-166, Corona, CA 92882
Office 951.545.2495 * Fax 951.346.3093

Laboratory Analytical Results/Sample Chains of Custody



LA Testing
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LA Testing Order: 321220880
CustomerID: 32FOCU65
CustomerPO:
ProjectID:

Attn: **Focus Environmental Consulting**
750 South Lincoln Avenue
Suite 104-166
Corona, CA 92882

Phone: (951) 545-2495
Fax:
Received: 12/07/12 4:25 PM
Analysis Date: 12/11/2012
Collected:

Project: **LAC/USC Tunnel, 1635 Marengo St., LA/Parking Lot Zonal & Mission**

Test Report: Asbestos Analysis of Bulk Materials via EPA 600/R-93/116 and/or EPA 600/M4-82-020 Method(s) using Polarized Light Microscopy

			Non-Asbestos		Asbestos
Sample	Description	Appearance	% Fibrous	% Non-Fibrous	% Type
10 321220880-0001	Tunnel/Large 12" Pipe/North	Beige Fibrous Heterogeneous		82% Non-fibrous (other)	15% Amosite 3% Chrysotile
11 321220880-0002	Tunnel/Large 12" Pipe/North				Stop Positive (Not Analyzed)
12 321220880-0003	Tunnel/Small 4" Pipe/North (Top)	White Fibrous Heterogeneous		82% Non-fibrous (other)	15% Amosite 3% Chrysotile
13 321220880-0004	Tunnel/Small 4" Pipe/North (Bottom)				Stop Positive (Not Analyzed)
14 321220880-0005	Tunnel/Small 4" Pipe/North				Stop Positive (Not Analyzed)

Analyst(s)
Rosa Mendoza (2)

Jerry Drapala Ph.D, Laboratory Manager
or other approved signatory

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Samples analyzed by LA Testing South Pasadena, CA NVLAP Lab Code 200232-0, CA ELAP 2283

Initial report from 12/11/2012 11:59:24

Test Report PLM-7.16.0 Printed: 12/11/2012 11:59:24 AM

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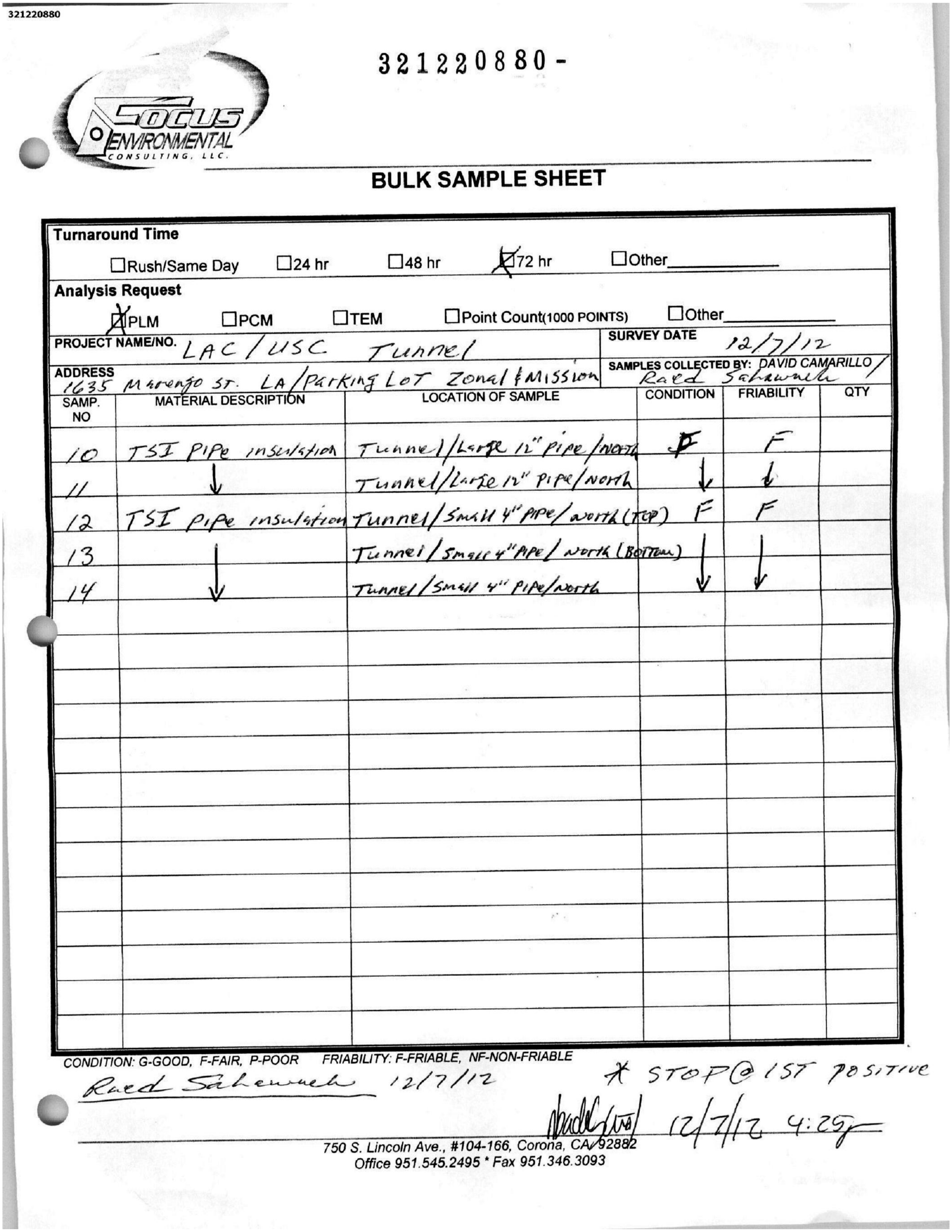
Laboratory Analytical Results/Sample Chains of Custody



321220880

321220880-

FOCUS ENVIRONMENTAL CONSULTING, LLC.

BULK SAMPLE SHEET

Turnaround Time

☐ Rush/Same Day ☐ 24 hr ☐ 48 hr ☒ 72 hr ☐ Other____________

Analysis Request

☒ PLM ☐ PCM ☐ TEM ☐ Point Count(1000 POINTS) ☐ Other____________

PROJECT NAME/NO. LAC / USC Tunnel

SURVEY DATE 12/7/12

ADDRESS 1635 Marengo ST. LA / Parking Lot Zonal & Mission

SAMPLES COLLECTED BY: DAVID CAMARILLO / Raed Sahawneh

SAMP. NO	MATERIAL DESCRIPTION	LOCATION OF SAMPLE	CONDITION	FRIABILITY	QTY
10	TSI Pipe insulation	Tunnel / Large 12" pipe / north	F	F	
11	↓	Tunnel / Large 12" pipe / north	↓	↓	
12	TSI pipe insulation	Tunnel / Small 4" pipe / north (TOP)	F	F	
13	↓	Tunnel / Small 4" pipe / north (BOTTOM)	↓	↓	
14	↓	Tunnel / Small 4" pipe / north	↓	↓	

CONDITION: G-GOOD, F-FAIR, P-POOR FRIABILITY: F-FRIABLE, NF-NON-FRIABLE

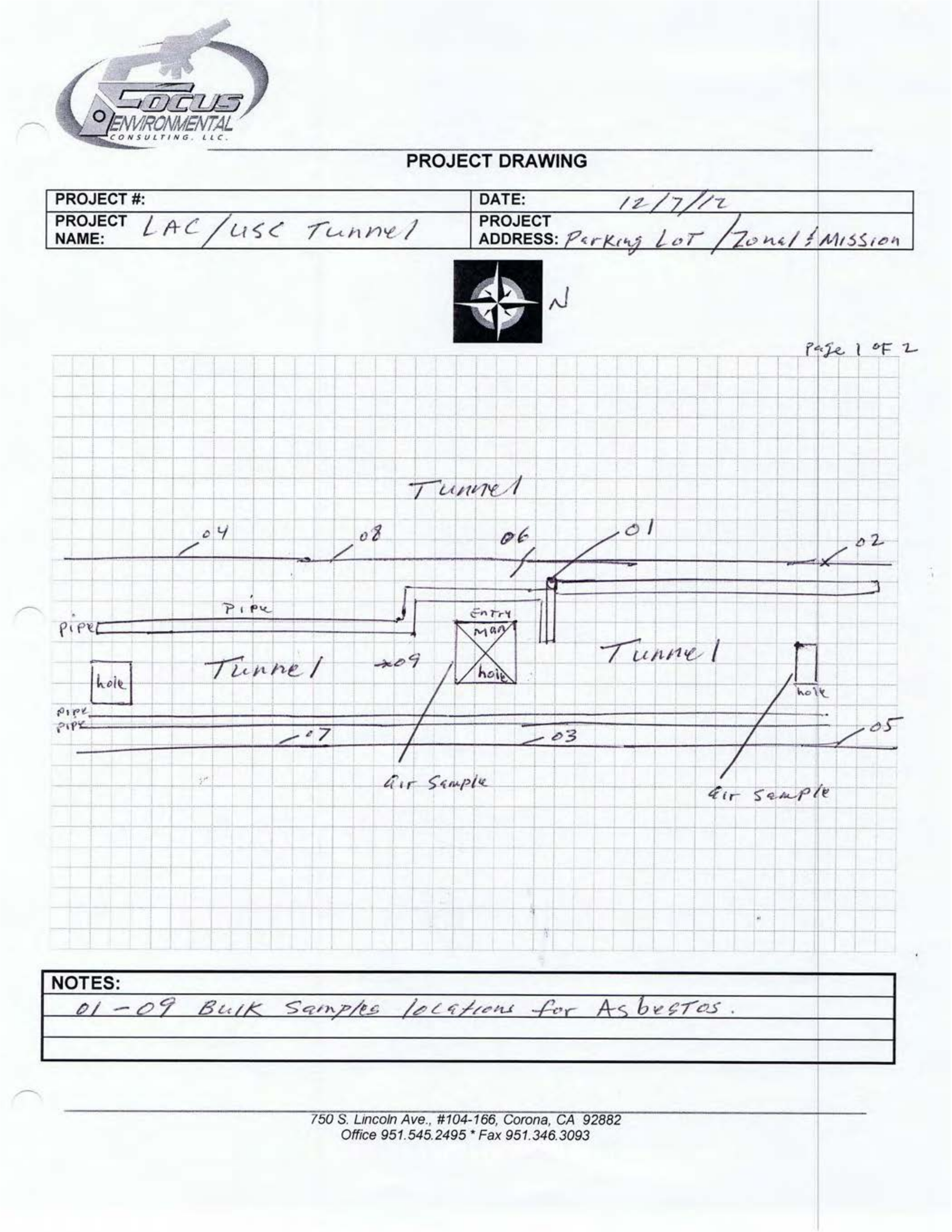
Raed Sahawneh 12/7/12

* STOP @ 1ST POSITIVE

12/7/12 4:25

750 S. Lincoln Ave., #104-166, Corona, CA 92882
Office 951.545.2495 * Fax 951.346.3093

Sample Location Drawings



PROJECT DRAWING

PROJECT #:	**DATE:** 12/7/12
PROJECT NAME: LAC/USC Tunnel	**PROJECT ADDRESS:** Parking Lot / Zonal & Mission

NOTES:

01-09 Bulk Samples locations for Asbestos.

750 S. Lincoln Ave., #104-166, Corona, CA 92882
Office 951.545.2495 * Fax 951.346.3093

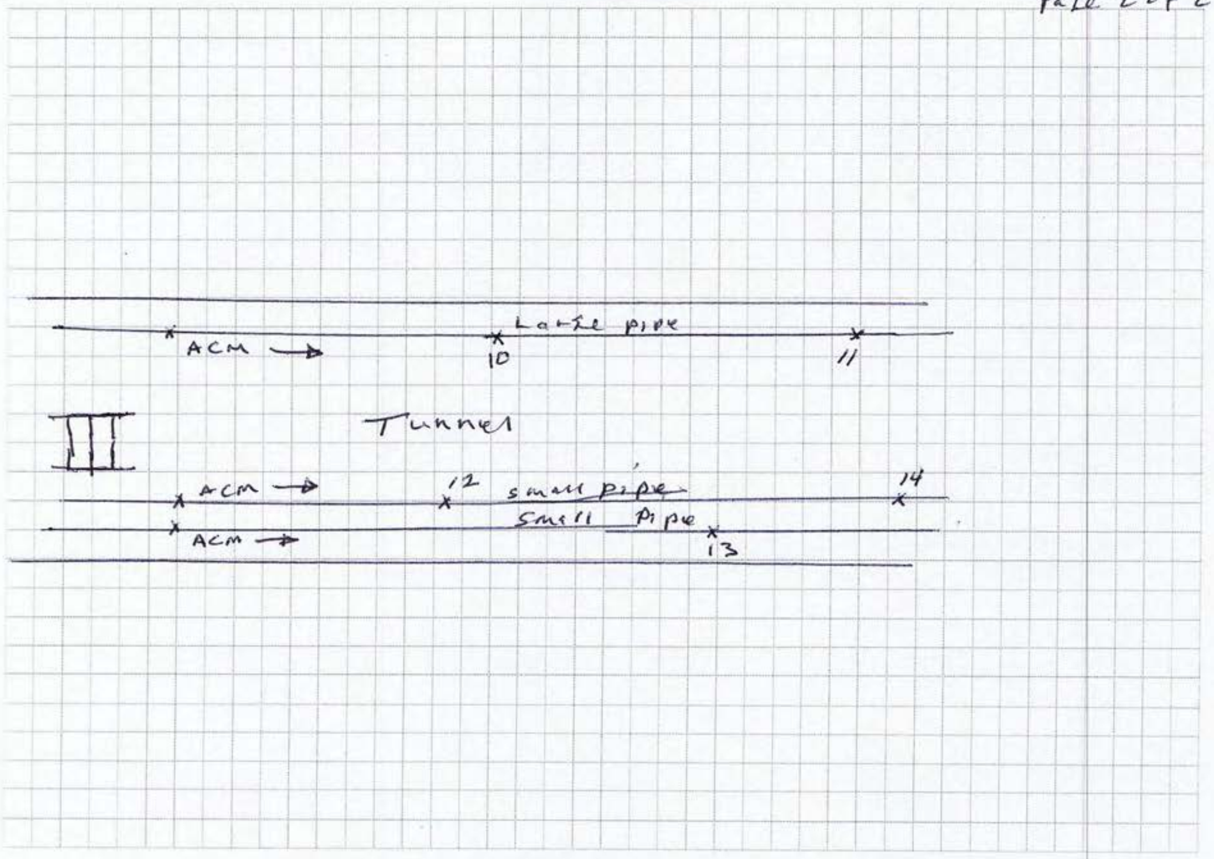
FOCUS ENVIRONMENTAL CONSULTING, LLC.

PROJECT DRAWING

PROJECT #:	**DATE:** 12/7/12
PROJECT NAME: LAC/USC Tunnel	**PROJECT ADDRESS:** Parking Lot/Zonal & Mission

N

Page 2 of 2



NOTES:

x 10-14 Bulk Samples location for Asbestos

750 S. Lincoln Ave., #104-166, Corona, CA 92882
Office 951.545.2495 * Fax 951.346.3093

Inspectors' Asbestos Certifications

State of California
Division of Occupational Safety and Health
Certified Site Surveillance Technician

David John Camarillo
Name

Certification No. 98-2424

Expires on 11/16/13

This certification was issued by the Division of Occupational Safety and Health as authorized by Sections 7180 et seq. of the Business and Professions Code.

State of California
Division of Occupational Safety and Health
Certified Site Surveillance Technician

Raed Farhan Sahawneh
Name

Certification No. 09-2692

Expires on 02/04/13

This certification was issued by the Division of Occupational Safety and Health as authorized by Sections 7180 et seq. of the Business and Professions Code.

State of California
Division of Occupational Safety and Health
Certified Asbestos Consultant

Rodica Dullabaun
Name

Certification No. 11-4716

Expires on 04/20/13

This certification was issued by the Division of Occupational Safety and Health as authorized by Sections 7180 et seq. of the Business and Professions Code.

JCE STRUCTURAL ENGINEERING GROUP, INC.

Structural Assessment Of

LAC+USC Medical Center/Utility Tunnel (Juvenile Hall)

Los Angeles, California

Prepared for:
Vanir Construction Management
&
LA County

By:
Juan Carlos Esquivel, M.S., S.E.

JCE JOB NO: 2012.037.1

July 11, 2012

TABLE OF CONTENTS

REGISTERED PROFESSIONAL ENGINEER
JUAN CARLOS ESQUIVEL
No. S 4074
Exp. 6-30-12
STRUCTURAL
STATE OF CALIFORNIA

1. INTRODUCTION

1.1. SCOPE OF WORK

JCE Structural Engineering Group, Inc. was contacted to perform a preliminary structural assessment of the structural conditions of and (E) Concrete Utilities Tunnel referred as Juvenile Hall Tunnel in this report.

2. TUNNEL DESCRIPTION

The South Side of the Juvenile Hall Tunnel was originally constructed approximately in 1930’s & the North Side seems to be newer than that but could not be verified with the available documentation. The dimensions of the (E) tunnel are approximately 4’-0” wide by 6’-0” high and is made of reinforced concrete walls & ceiling. The thickness of the (E) walls or ceiling were not available in any drawings. Since the scope of work did not include to perform any NDT testing, we do not have any information of the (E) concrete strength or the exact size of the (E) rebars at this time.

3. WORK METHODOLOGY

JCE Structural Engineering Group, **Inc.** work methodology is as follows:

A) Job site visit

JCE visited the area of the existing building on two occasions.

- The first job site visit was on April 3rd and we visited many other (E) tunnels in the campus, but unfortunately we could not access to The Juvenile Hall because the steam pipes were in use and it was extremely hot inside and not safe to enter.
- The second job site visit was performed on June 29th after coordination with LAC+USC M.C. personnel to have the steamer being shut down the night before to be able to enter the tunnel safely. Juan Carlos Esquivel, Principal in charge of JCE Structural Engineering Group & Scott Landsburg from Ace Restoration (Contractor) performed the following:

  - Walked inside the tunnel from location 32 (Manhole located at about middle of the parking lot: see Fig. 1 & Photo 1.) to the North end of the parking lot to perform visual inspection of the tunnel. Once we reached the North end of the tunnel, the alarm of the sniffer went on detecting large amount of toxic gases (H2S which is lethal), and we needed to evacuate the tunnel and could not get back to inspect the South Side of the tunnel.
  - Took pictures of various damaged areas of the North Side of the tunnel to gather information for our structural visual assessment of the conditions of the (E) tunnel and its repair feasibility.

B) Review of available documentation

- Review of “Evaluation Of The Utility Tunnels” report prepared by Bock Engineering, Inc dated July 25, 2003.
- Review of Section 3 “Existing Tunnel Systems” & drawing sheets: R676-1, R676-2, R676-3 & R676-4, prepared by The Ralph M. Parsons Company in 1975.

C) Repair Alternatives Discussions

- Discussed with our Contractor the pros and cons of different Repair alternatives.

4. FINDINGS & OBSERVATIONS

From our visual inspection of the current structural conditions of the North Side of The Juvenile Hall Tunnel, as well as based on our review of the available reports (see References), we have observed the following:

- At many locations the ceiling of the tunnel has been completely delaminated and spalled. Many of the reinforcing bars are exposed, severely corroded & in some instances have lost most of their section or are completely broken. See photos 2, 3 & 4.
- At many other locations the ceiling of the tunnel shows severe signs of delamination and large cracks and the concrete is ready to be spalled. This is a clear indication that reinforcing inside the concrete ceilings have been severely corroded. See photo 5.
- At many wall locations the concrete has also spalled and there are many corroded and exposed reinforcing bars shown. Many of them show severe reduction of their original section, some of them are bent and others are completely broken. See photos 2 & 6 to 14.
- Large vertical, horizontal & diagonal cracks in the ceiling & walls have been observed. See photos 2, 5 & 14.
- Although we were not able to enter to the South Side of the tunnel, from review of previous report by Bock Engineering, it appears that similar distressed conditions and damage exist at many locations.

5. STRUCTURAL STRENGTHENING REPAIR DISCUSSION

Based on the findings & observations above, we will suggest to consider the following (2) major alternatives:

A) Structural Strengthening Repair of the (E) tunnel.

In order to strengthen the (E) tunnel, a NDT program shall be performed first to determine the (E) concrete strength, (E) concrete ceiling and wall thickness, (E) rebars size, spacing and location, to be able to determine the original structural capacity of the (E) tunnel. We also recommend a corrosion study to determine other areas of potential corrosion besides the obvious ones. Based on the results of the NDT program, the results of the structural capacity of the (E) tunnel, and the corrosion study a variety of structural strengthening repair techniques shall be study to determine the most suitable for this project. Among them are:

- Shotcrete
- Fiberwrap
- Local Patch & Repair (involving doweling new bars, corrosion protection, patch repair & additional concrete cover)

In any of the above repair solutions the first item of action is to find the origin of the problem which most likely is water intrusion and resolve it. The second item of action is to control the corrosion issues of the (E) rebars & quantify the extent of it (corrosivity studies). There are many ways to control the corrosion and are based on their severity. Some of the corrosion repair techniques are: Metalized Coatings, Electrochemical Treatment, Galvanic Cathodic Protection System or Current Cathodic Protection System. Any Structural Strengthening Repair to restore the original (E) capacity of the tunnel structure or to improve it shall also address the water intrusion and corrosion issues.

B) Relocate the low pressure steam piping and buried the tunnel.

6. EXECUTIVE SUMMARY

From our job site investigation, review of (E) documents and findings & observations, the tunnel **SHALL NOT BE ACCESSED** for the time being due to the safety hazards involved (structural & toxic gases.) It is our professional opinion that in order to choose the best course of action for LA County in regards to the Juvenile Hall Tunnel, a Structural Strengthening Repair Scheme based on the above parameters shall be performed with their respective construction cost estimate and compare it with the cost of relocating the Low pressure steam piping and buried the tunnel. In addition the construction time of both alternatives shall be put in balance for the final selection of the course to take by LA County.

At this time, it is our initial opinion that it is feasible to repair the tunnel but due to the extent of the repair it may be cost prohibitive and needs to be determined in a subsequent phase & from the comparison of the two major alternatives mentioned in item 5 above.

7. DISCLAIMER

Our professional services have been performed with the intent to meet the degree of care and skill ordinarily exercised by reputable Structural Engineers practicing in this or similar localities and under similar conditions. No other warranty, expressed of implied, is made as to the professional advice or opinions included in this report.

8. APPENDIX

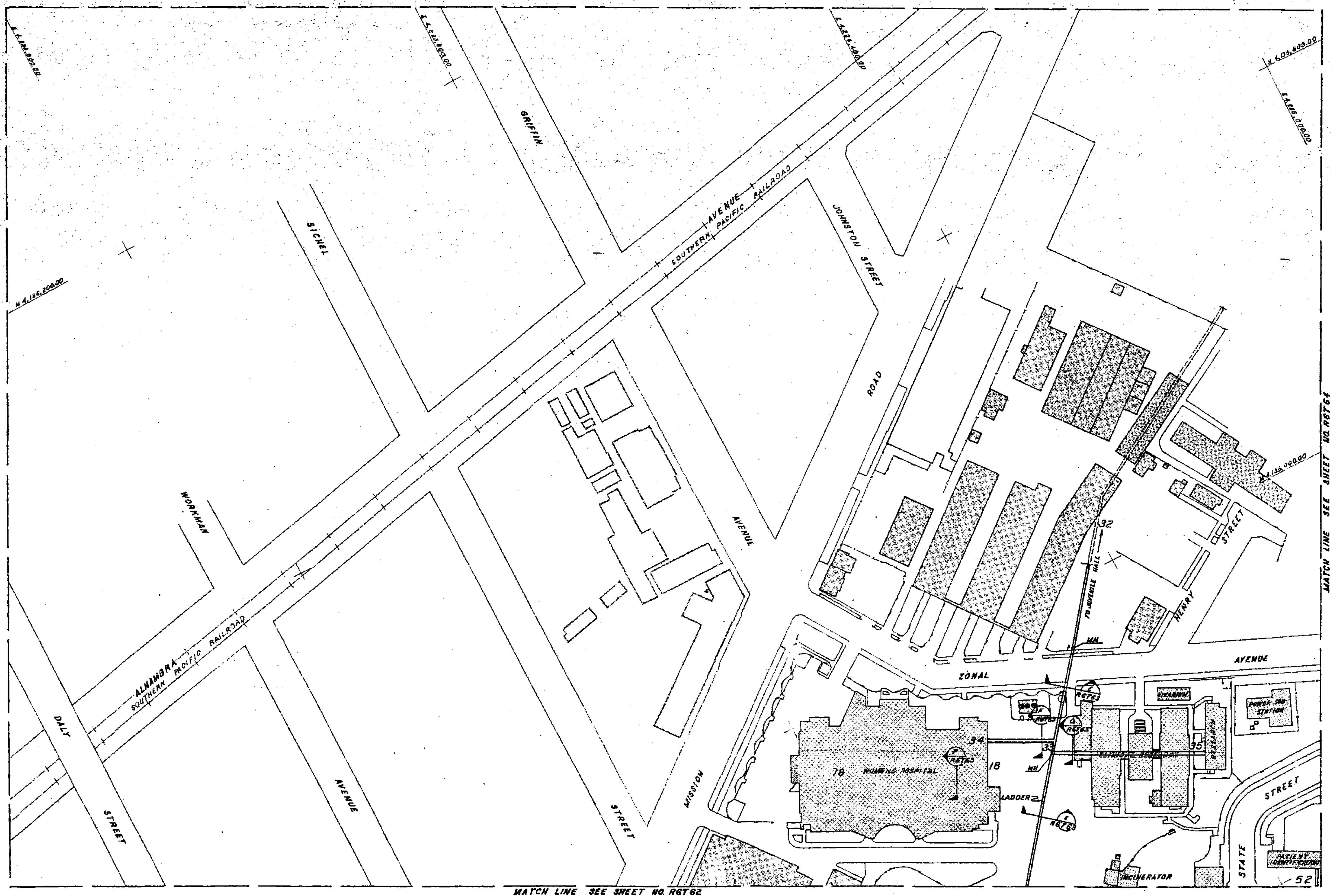
8.1 Figures & Photos

9. REFERENCES

A. Evaluation Of The Utility Tunnels Report by Bock Engineering, Inc. dated July 25, 2003.
B. Section 3 - Existing Tunnel Systems from Ralph M. Parsons Company report done in 1975.
C. Sheet dwg Nos R676-1, R676-2, R676-3 & R676-4 by Ralph M. Parsons Company dated 1975.

APPENDIX 8.1

FIGURES & PHOTOS



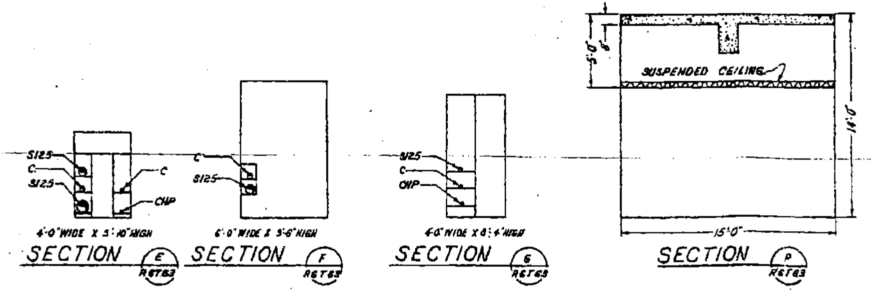
MATCH LINE SEE SHEET NO. R6T62

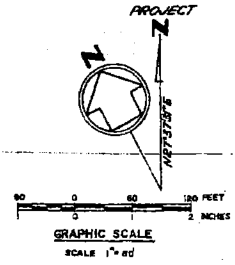
LEGEND

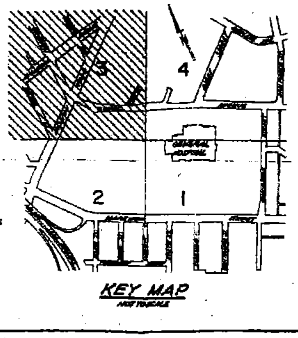
S125 ___ STEAM PRESSURE 125 PSI
C ___ CONDENSATE RETURN
CHP ___ CONDENSATE HIGH PRESSURE RETURN

NOTE:

THE LARGER NUMBERS SHOWN ON THIS PLAN ARE USED IN THE REPORT ON EXISTING CONDITION SECTION #3 TUNNEL SYSTEM







KEY MAP
NOT TO SCALE

THE RALPH M. PARSONS COMPANY, ENGINEERS • CONSTRUCTORS 100 WEST WALNUT STREET, PASADENA, CALIFORNIA 91124 (213) 440-2000

UTILITY SYSTEMS RECORD DRAWING - 1975

TUNNEL SYSTEM

NOV 24 1975

LAC/USC MEDICAL CENTER
1200 NORTH STATE STREET
LOS ANGELES, CALIFORNIA 90032

COUNTY OF LOS ANGELES
FACILITIES DEPARTMENT
STEPHEN J. KOONCE - DIRECTOR
1525 W. OLYMPIC BLVD. (213) 974-1901
LOS ANGELES, CALIFORNIA 90015

MARK	REVISION	DATE	BY	NUMBER	REVISION	DATE	BY		

PROJECT MANAGER
PROJECT ENGINEER
DESIGNED BY
DRAWN BY
CHECKED BY
DATE

CAPITAL PROJECT
7790.22
SPEC. NO.
3394
SHEET NO.
R6T63

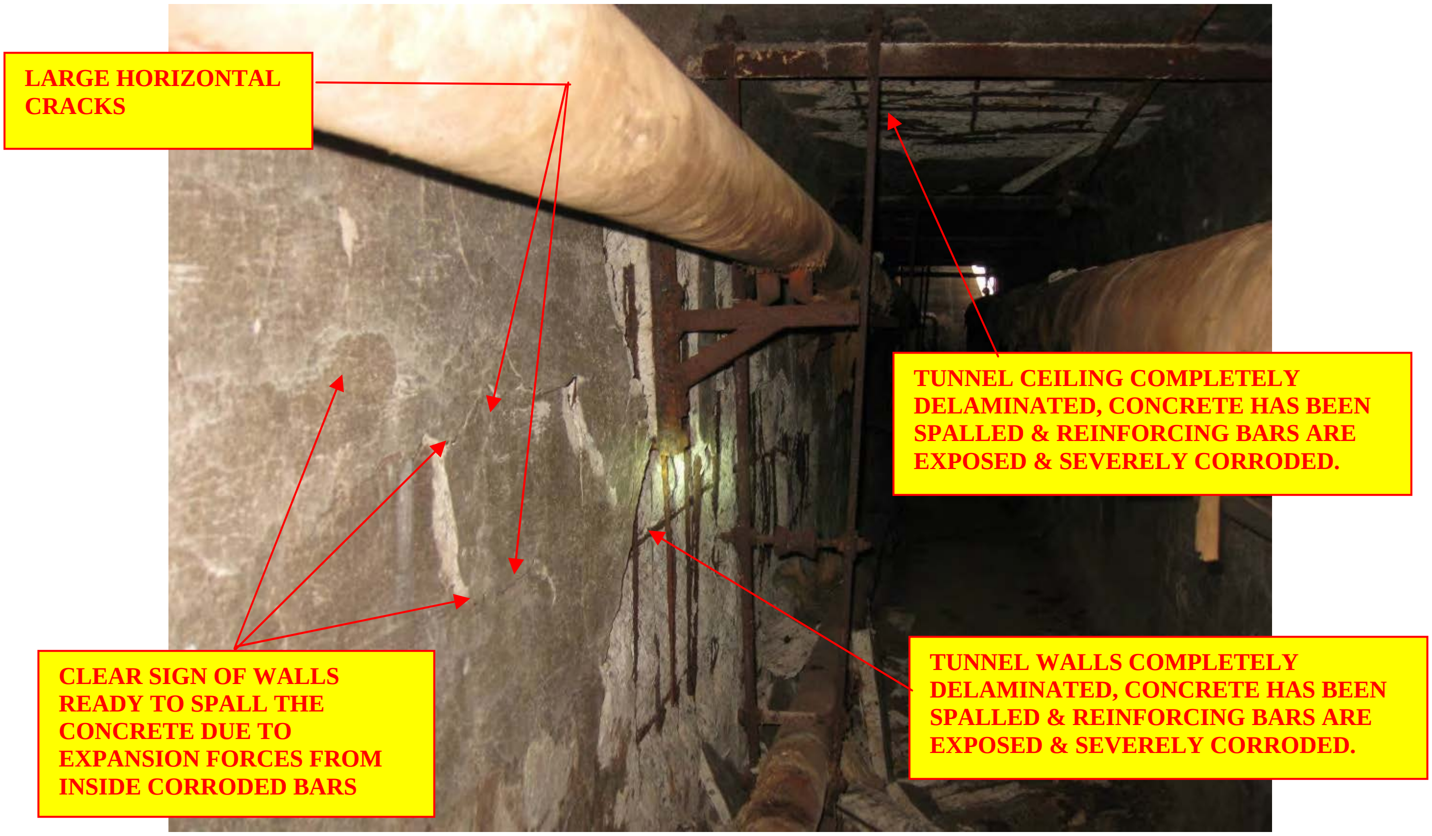
244

67

9-72 NMP 215 REV.4

MANHOLE ENTRANCE LOCATED AT MIDDLE OF PARKING LOT ABOVE JUVENILE HALL TUNNEL

PHOTO 1: MANHOLE ENTRANCE TO JUVENILE HALL TUNNEL.



LARGE HORIZONTAL CRACKS

TUNNEL CEILING COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED & REINFORCING BARS ARE EXPOSED & SEVERELY CORRODED.

CLEAR SIGN OF WALLS READY TO SPALL THE CONCRETE DUE TO EXPANSION FORCES FROM INSIDE CORRODED BARS

TUNNEL WALLS COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED & REINFORCING BARS ARE EXPOSED & SEVERELY CORRODED.

PHOTO 2: TUNNEL CEILING & WALLS

METAL IRON COMPLETELY CORRODED SHOWING THE HIGH CORROSIVITY ENVIRONMENT INSIDE THE TUNNEL

TUNNEL CEILING:
CLOSE-UP OF EXPOSED REINFORCING BARS, COMPLETELY CORRODED & BROKEN

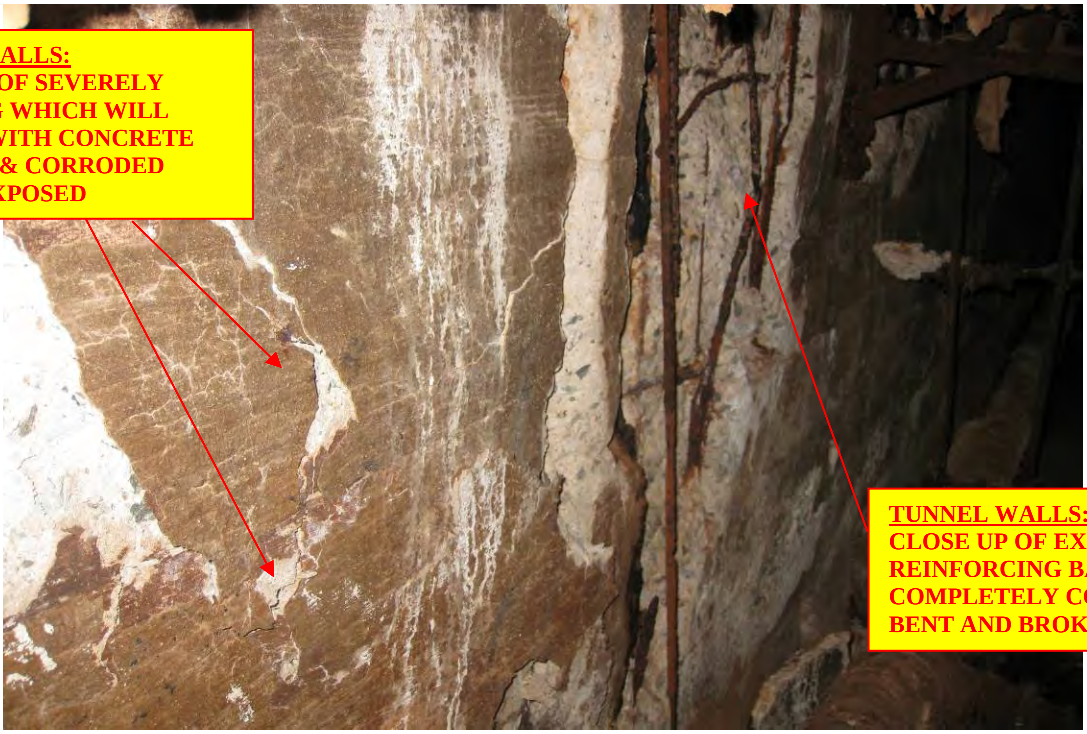
PHOTO 3: TUNNEL CEILING

TUNNEL CEILING:
CLOSE-UP OF EXPOSED REINFORCING BARS, COMPLETELY CORRODED & BROKEN

PHOTO 4: TUNNEL CEILING

TUNNEL CEILING:
CLOSE-UP OF DELAMINATION & LARGE CRACKS. CONCRETE IS READY TO BE SPALLED & FALL DOWN.

PHOTO 5: TUNNEL CEILING



TUNNEL WALLS:
CLOSE UP OF SEVERELY CRACKING WHICH WILL FOLLOW WITH CONCRETE SPALLING & CORRODED REBARS EXPOSED

TUNNEL WALLS:
CLOSE UP OF EXPOSED REINFORCING BARS, COMPLETELY CORRODED, BENT AND BROKEN

PHOTO 6: TUNNEL WALLS

TUNNEL WALLS:
CLOSE UP OF EXPOSED REINFORCING BARS, COMPLETELY CORRODED, BENT AND BROKEN

PHOTO 7: TUNNEL WALLS

TUNNEL WALLS COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED. REINFORCING BARS ARE EXPOSED & SEVERELY CORRODED.

PHOTO 8: TUNNEL WALLS

TUNNEL WALLS COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED. REINFORCING BARS ARE EXPOSED, SEVERELY CORRODED, BENT & BROKEN

PHOTO 9: TUNNEL WALLS

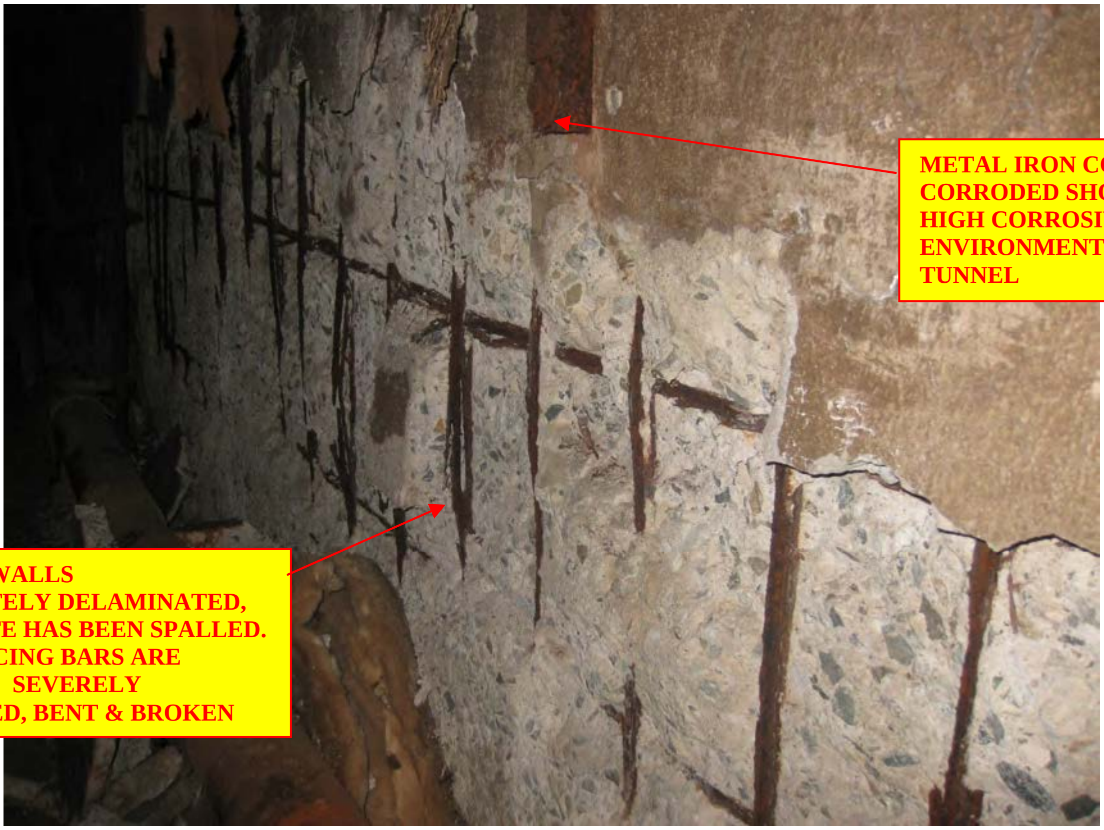
TUNNEL WALLS COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED. REINFORCING BARS ARE EXPOSED, SEVERELY CORRODED, BENT & BROKEN

METAL IRON COMPLETELY CORRODED SHOWING THE HIGH CORROSIVITY ENVIRONMENT INSIDE THE TUNNEL

PHOTO 10: TUNNEL WALLS

TUNNEL WALLS COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED. REINFORCING BARS ARE EXPOSED, SEVERELY CORRODED, BENT & BROKEN

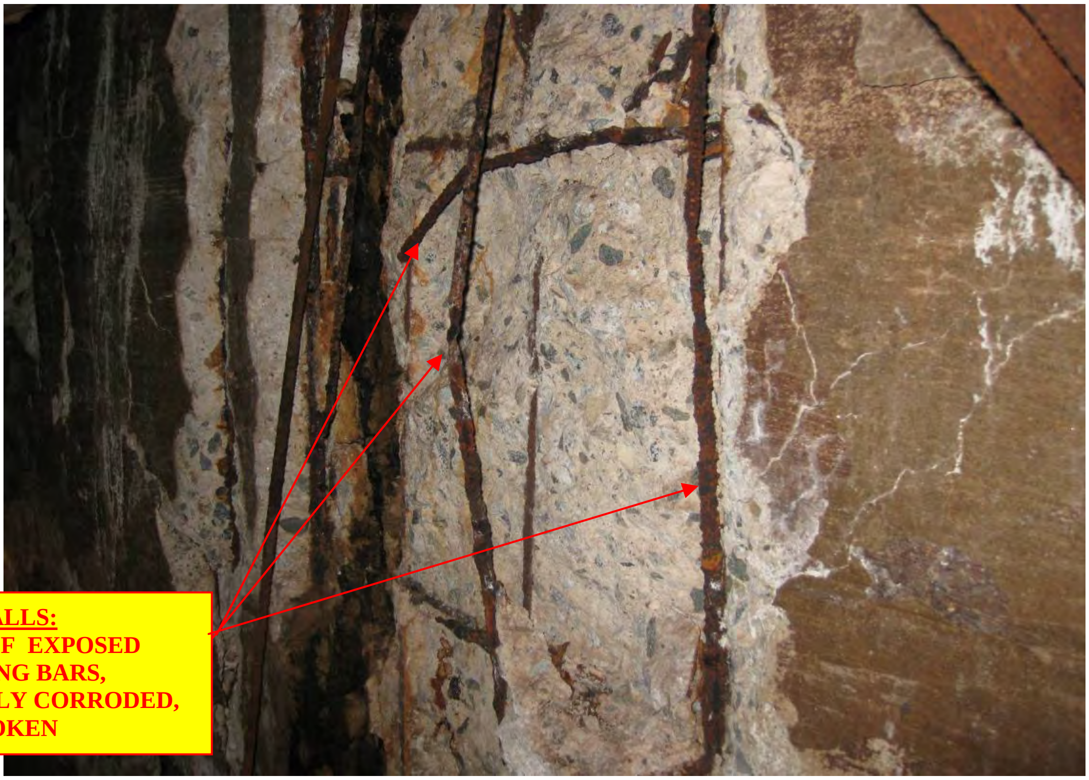
PHOTO 11: TUNNEL WALLS



METAL IRON COMPLETELY CORRODED SHOWING THE HIGH CORROSIVITY ENVIRONMENT INSIDE THE TUNNEL

TUNNEL WALLS COMPLETELY DELAMINATED, CONCRETE HAS BEEN SPALLED. REINFORCING BARS ARE EXPOSED, SEVERELY CORRODED, BENT & BROKEN

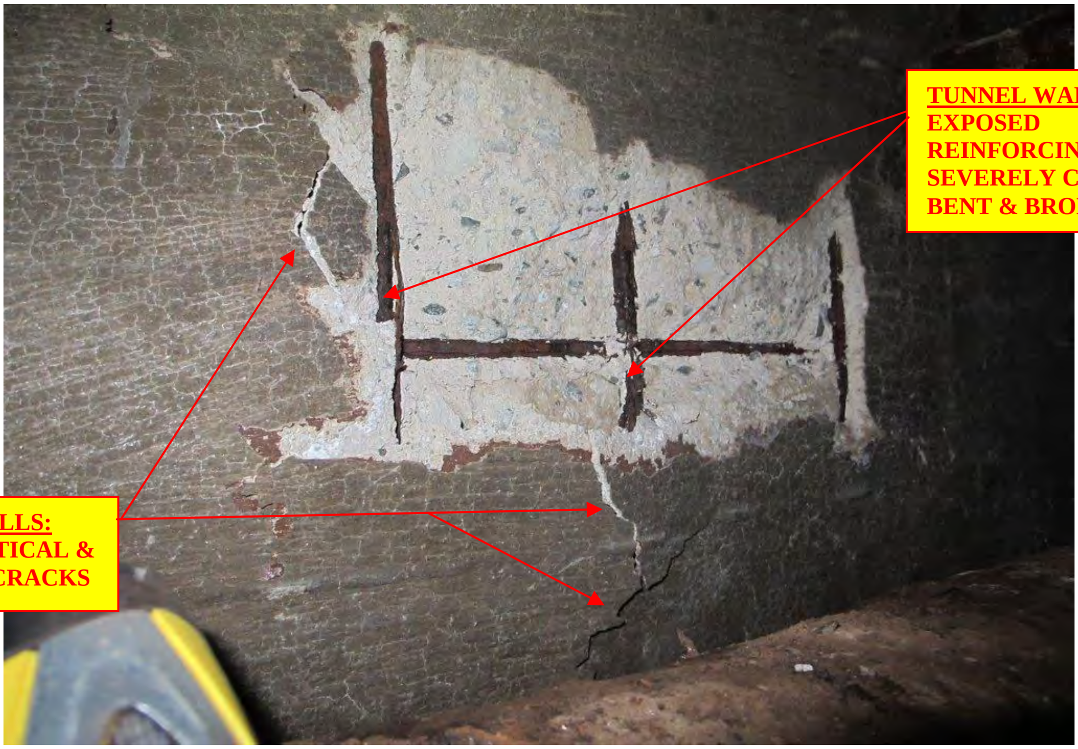
PHOTO 12: TUNNEL WALLS



TUNNEL WALLS:

CLOSE UP OF EXPOSED REINFORCING BARS, COMPLETELY CORRODED, BENT & BROKEN

PHOTO 13: TUNNEL WALLS



<u>TUNNEL WALLS:</u>
EXPOSED REINFORCING BARS, SEVERELY CORRODED, BENT & BROKEN

<u>TUNNEL WALLS:</u>
LARGE VERTICAL & DIAGONAL CRACKS

PHOTO 14: TUNNEL WALLS

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