METROPOLITAN
TRANSPORTATION
COMMISSION

Bay Area Metro Center
375 Beale Street, Suite 800
San Francisco, CA 94105
415.778.6700
www.mtc.ca.gov

April 3, 2019

The Honorable London N. Breed
Mayor, City of San Francisco
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

The Honorable Libby Schaaf
Mayor, City of Oakland
City Hall
1 Frank H. Ogawa Plaza
Oakland, CA 94612

RE: Transbay Transit Center Peer Review

Dear Mayor Breed and Mayor Schaaf:

I write you to provide an update on the progress of the expert panel assembled by MTC to review the cause and repair of fractured girders at the Transbay Transit Center. I also want to clarify the scope of this panel's findings to date and expectations for future findings and recommendations.

In response to your October 4, 2018 letter, MTC selected a panel of experts, the Peer Review Panel, to provide an independent review of the cause of failure analysis and repair design so that you and the public may have a high level of confidence that the girders are structurally safe once the Transit Center reopens to the public. The Peer Review Panel is comprised of experts in the fields of structural steel design, fracture mechanics, and steel construction for this purpose. Dr. Michael Engelhardt, a professor of civil engineering at the University of Texas at Austin, chairs this panel.

The Peer Review Panel has reviewed analyses performed by consultants under contract with the Transbay Joint Powers Authority (TJPA) that: identify the conditions present in the steel girders that contributed to the fractures; and inform the repair design. The progress of the peer review is outlined in the attachment. There is broad consensus among the Peer Review Panel and TJPA consultants on these conditions that caused the fractures. There is also agreement on the design of the girder repair at Fremont Street and retrofit at First Street.

The TJPA staff recently announced it believes the steel subcontractor is the party responsible for the fracture based on a series of decisions and actions associated with fabrication of the holes cut in the flanges of the girders. This statement reflects TJPA's interpretation of code and contractual terms and responsibilities. Note that the Peer Review Panel was not asked to and does not intend to address this line of inquiry concerning which parties were responsible for the fractures, and whether the work was in compliance with code or contract provisions.

The Peer Review Panel will continue with its directive to understand the failure mechanism and ensure the repairs are appropriate. At the present time, the repair and retrofit are being installed. Concurrently, TJPA staff is searching through records and performing new inspections as necessary to determine if there are other locations susceptible to brittle

fracture, and whether any additional retrofits are required. The Peer Review Panel has concurred with the criteria being used for this search and will review the results.

In addition, MTC has asked the Peer Review Panel, as it completes its work, to comment on lessons learned from this incident. These will likely take the form of rather broad recommendations on issues this panel believes should be considered by the industry to help avoid this type of failure in the future.

Thank you for your continued support and concern for the safety of our transit riding public. We will continue to keep you updated as progress is made. Please do not hesitate to contact me with any questions or concerns in the meantime.

Sincerely,

Therese W. McMillan
Executive Director

cc:
Scott Haggerty, Chair, Metropolitan Transportation Commission
Michael Engelhardt, Chair, Peer Review Panel
Mohammad Nuru, Chair, Transbay Joint Powers Authority
Mark Zabaneh, Executive Director, Transbay Joint Powers Authority
Ramakrishna Pochiraju, Executive Director of Planning & Engineering, AC Transit

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Attachments

Transbay Transit Center Fractured Girder
MTC Peer Review Status
April 3, 2019

Schedule

Milestones to Date:

- August 12, 2018: Transit Center opens for bus operations.
- September 25, 2018: Workers installing ceiling panels discover a fracture in the bottom flange of a girder over Fremont (see Images 1-3 on page 3). TJPA closes the Transit Center. In the following days, TJPA discovers a fracture in a second similarly designed girder over Fremont Street. Two other girders over First Street share the design of the fractured girders but remain intact. TJPA installs shoring at Fremont and First Street.
- October 4, 2018: The mayors of Oakland and San Francisco write a letter to MTC requesting MTC provide an independent evaluation of the cause of failure and repair. Subsequently, MTC assembles a Peer Review Panel (PRP) consisting of experts in steel design and construction, structural analysis, and fracture mechanics.
- December 13, 2018: TJPA presents to its board the failure hypothesis based on materials analysis and the preliminary design for the repair. PRP concurs.
- January 2019: TJPA begins search for other areas susceptible to brittle fracture.
- February 14, 2019: TJPA reports to its board that it will retrofit First Street similar to the Fremont Street repair. PRP concurs.

Next Steps:

- April 2019: Final computational analysis results for cause of failure are expected to be received for peer review.
- June 2019: TJPA projects the Fremont Street repair and First Street retrofit will be complete.
- Reopening of the Transit Center for bus operations: Dependent on completion of the repair and retrofit and resolution of the search for other areas susceptible to brittle fracture.

Participants

TJPA's project team:

1. Thornton Tomasetti: Structural Engineer of Record
2. LPI: Failure investigation and fitness for service consultant
3. Webcor: General contractor
4. Skanska: Steel subcontractor
5. Herrick: steel fabricator of fractured girders and repair

PRP:

1. Michael Engelhardt, Chair, Univ. of Texas
2. John Fisher, Lehigh University
3. Tom Sabol, Englekirk Companies
4. Bob Shaw, Steel Structures Tech. Center
5. Brian Kozy, FHWA

Support to PRP:

1. Bill Mohr, Edison Welding Institute
2. David Ruby, Ruby + Associates

Scope and Status of Peer Review

MTC divided the scope of the peer review into six parts, as follows:

1. **Shoring capacity: Reviewed and concurred.**
   Shores were added below the Fremont Street and First Street girders to provide an alternative load path. The PRP reviewed the design to ensure the shores had sufficient capacity and stability.

2. **Sampling and testing plan: Reviewed and concurred.**
   TJPA's project team developed a plan to remove steel surrounding the fracture and test it to provide data to support the failure analysis.

3. **Cause of failure: General concurrence with findings; pending final report.**
   In December 2018, the results of the material testing pointed to a preliminary hypothesis that the cause of failure was a result of: material properties (low fracture toughness at the mid-thickness of four-inch-thick steel plates); the presence of initiating defects (micro-cracks introduced by the flame cutting of slots); and stress across the fracture plane (residual stress due to adjacent welding, and applied stress from loads on the girders after erection).

4. **Impact of fractures on adjacent elements: Review nearing completion.**
   When the girders fractured, the existing static load would have redistributed to adjacent elements and a dynamic pulse load would have also traveled through them. Based on preliminary calculations and non-destructive testing, LPI concluded no adjacent members were compromised. Some additional analysis and testing will be conducted by LPI for peer review.

5. **Repair of Fremont Street girders: Reviewed and concurred.**
   The preliminary hypothesis from material testing provided enough knowledge of the cause of failure to allow Thornton Tomasetti to design a repair. The repair is a sandwich of steel plates bolted across the fractures (See Image 4 on page 3). The design of the girders at Fremont Street is replicated at First Street. Differences in fabrication reduced the risk of fracture at First Street, but TJPA will implement a retrofit to the First Street girders similar to the repair of the Fremont Street girders as a precautionary measure.

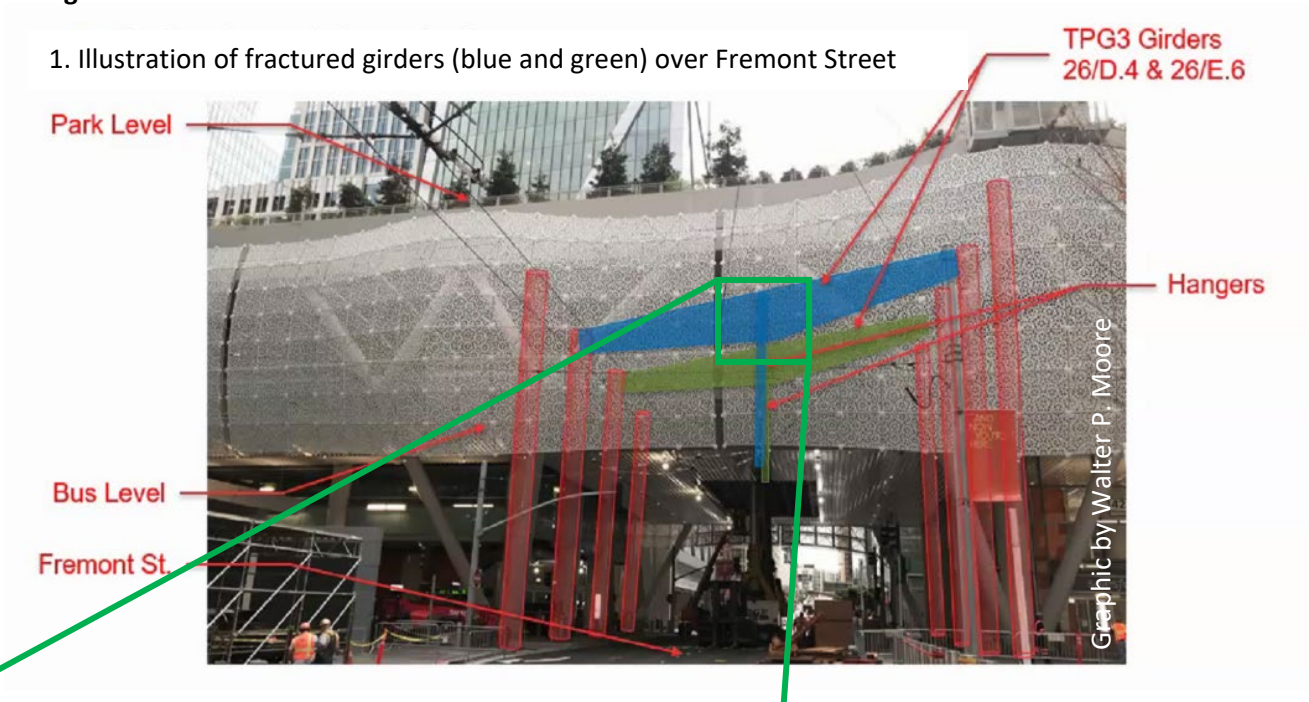
6. **Search for other areas susceptible to brittle fracture: Concurrence with criteria; review of TJPA project team's work on-going.**
   Although no other locations share the exact same design as the girders at Fremont and First Streets, the factors that led to brittle fracture (material properties, initiating defects, and stress) may be present elsewhere. TJPA's project team has developed criteria to filter the components of the steel structure down to the locations, if any, that need to be retrofitted, and is currently conducting this search.

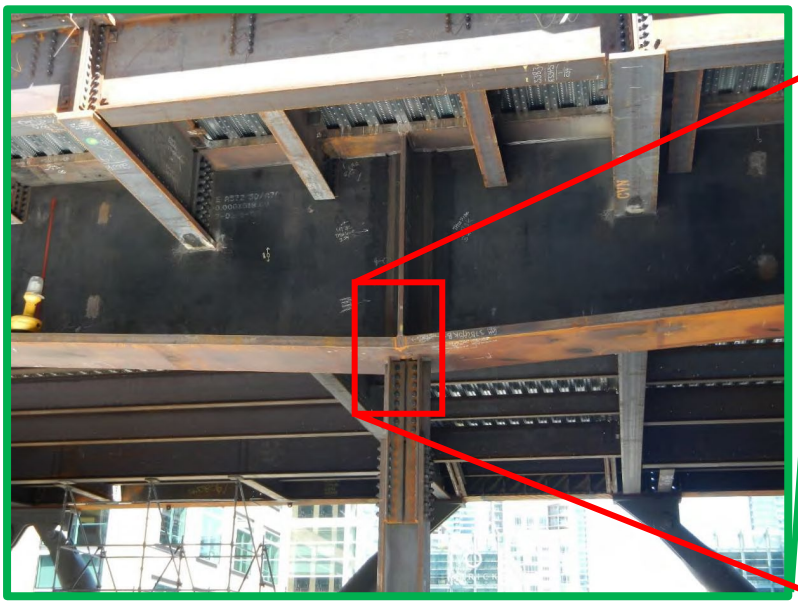
The Peer Review Panel will review work completed by the TJPA project team; it is not performing a separate analysis. The Peer Review Panel will not determine responsibility, nor will it evaluate whether work complied with code or contract documents, but it will make recommendations for changes to code and industry standards to help avoid this type of failure in the future.

The Peer Review Panel's letters of concurrence to MTC for Parts 1, 2, and 5 are attached.

Images

1. Illustration of fractured girders (blue and green) over Fremont Street





2. Hanger-to-girder connection at site of fracture (before fracture)

3. Fracture through bottom flange

4. Bolted sandwich plate repair

March 15, 2019

Stephen Wolf, P.E.
Principal
Metropolitan Transportation Commission
Bay Area Metro Center
375 Beale Street, Suite 800
San Francisco, CA 94105

RE: Transbay Transit Center
Review of Temporary Shoring Systems at Fremont Street and First Street

Dear Stephen:

This Peer Review Panel (PRP) was assembled by MTC at the request of the mayors of San Francisco and Oakland to review the activities undertaken in response to the fractured girders at the Transbay Transit Center (TTC). Our review was initially divided into the following five phases:

1. Capacity of the temporary shoring systems.
2. Sampling and testing plan for material from the fractured steel girders.
3. Cause of failure.
4. Impact of fractures on adjacent elements.
5. Repair of Fremont Street girders.

The results of the initial review may lead the panel to recommend other related investigations and analyses, which the panel may also subsequently review.

The purpose of this memo is to document the completion of our review of Phase 1, capacity of the temporary shoring systems. Our review included the temporary shoring systems both at Fremont Street and at First Street, installed to provide an alternative load path from the four TPG3 girders. In both cases, we did not review the initial shoring systems installed on an emergency basis that involved the use of very large hydraulic jacks placed at streel level provided by Bigge Crane and Rigging. Our review covered the subsequent more permanent, albeit still temporary, shoring systems that employed the use of hydraulic rams at street level provided by Sheedy Drayage Company.

Our review of the Fremont and First Street shoring systems was to ensure TJPA's project team performed proper due diligence in developing the design. We looked at the basis of design, structural concept and layout, overall stability, selected critical details, and selected calculations. Our scope did not include an in-depth review of all design details

and calculations nor a check for code compliance as this was done by other parties engaged by TJPA.

The process and results of our review are summarized separately below for the Fremont Street shoring and the First Street shoring.

Fremont Street Shoring

The review process included numerous online meetings between Thornton Tomasetti and the PRP. The major documents reviewed by the PRP throughout this process are as follows:

- Reports dated October 8 and October 10, 2018 by Thornton Tomasetti, titled: *Salesforce Transit Center – Fremont Street Shoring – Structural Calculations.*
- Memo dated October 13, 2018 from Steven Brokken of AECOM to Mark O'Dell of TJPA, with the subject: *Peer Review of Thornton Tomasetti Fremont Street Shoring at the Salesforce Transit Center.*
- Memo dated October 22, 2018 from Bruce Gibbons of Thornton Tomasetti to Mark O'Dell of TJPA, with the subject: *Shoring Design Peer Review Comments.*
- Drawings of the shoring system by Thornton Tomasetti, in the files: "20181022 TempShoringSet_TT.pdf," and "20181022 TempShoringSet_r1.pdf"
- Drawings and calculations by Thornton Tomasetti, in the file: "20181025 Stress Check in TPG3 @ GLE.6 with Composite Section Modulus.pdf"
- Memo dated October 30, 2019 from John Abruzzo to Dennis Turchon titled: *TPG-3 Grid Line 26 Bus Deck Shoring - Brace Calculation.*
- Drawings and calculations by Thornton Tomasetti, in the file: "20181205 Bending and Shear Demands in Fremont Shoring Due to Seismic Rocking.pdf"
- Drawings and calculations by Thornton Tomasetti, in the file" TPG3 Demands with reduced Jacking Forces 10-24-18.pdf"
- Drawings of the shoring system by Thornton Tomasetti, in the file: "TempShoringAtFremontStSet_TT20190108_wStamp.pdf"
    - Sheets: S1-8105; S1-8120 to 8123; S1-8130 to 8138.

Thornton Tomasetti addressed questions and comments from the PRP throughout this process. The PRP concurs with the design of the shoring system at Fremont Street. The basis of our concurrence is the final set of design drawings, which is the last item in the list above ("TempShoringAtFremontStSet_TT20190108_wStamp.pdf"), combined with the installation of additional lateral bracing for the W36x529 spreader beams at the bus deck level. This additional lateral bracing is not shown on the final set of design drawings, but has been installed.

First Street Shoring

The review process included numerous online meetings between Thornton Tomasetti and the PRP. The major documents reviewed by the PRP throughout this process are as follows:

- Report dated November 9, 2018 by Thornton Tomasetti, titled: *Salesforce Transit Center – First Street Shoring – Structural Calculations*
- Memo dated December 3, 2018 from Steven Brokken of AECOM to Mark O'Dell of TJPA, with the subject: *Review of Salesforce Transit Center First Street Shoring.*
- Calculations dated December 20, 2018 by Thornton Tomasetti, titled: *Hanger Compression Check.*
- Drawings of the shoring system by Thornton Tomasetti, in the file: "TempShoringAtFirstStreetSet_TT20181112_wStamp.pdf"
- Drawings of the shoring system by Thornton Tomasetti, in the file: "TempShoringAtFirstStreetSet_TT20181113_wStamp.pdf"
- Drawings of the shoring system by Thornton Tomasetti, in the file: "TempShoringAtFirstStreetSet_TT20190108_wStamp.pdf"
    - Sheets: S1-8205; S1-8220 to 8222; S1-8230 to 8231; S1-8234.

Thornton Tomasetti addressed questions and comments from the PRP throughout this process. The PRP concurs with the design of the shoring system at First Street. The basis of our concurrence is the final set of design drawings, which is the last item in the list above ("TempShoringAtFirstStreetSet_TT20190108_wStamp.pdf").

While the PRP has reviewed and concurs with the design of the shoring systems at Fremont Street and at First Street, the responsibility for the design remains with the engineer of record, and the in-depth engineering design check and regulatory review were done by others.

Sincerely,

Michael D. Engelhardt, P.E., Ph.D.
Chair, Peer Review Panel

c. Members of PRP:
John Fisher
Brian Kozy
Thomas Sabol
Robert Shaw

March 9, 2019

Stephen Wolf, P.E.
Principal
Metropolitan Transportation Commission
Bay Area Metro Center
375 Beale Street, Suite 800
San Francisco, CA 94105

RE: Transbay Transit Center
Review of TJPA Sampling and Testing Plan for Material from Fremont Street Girders

Dear Stephen:

This Peer Review Panel was assembled by MTC at the request of the mayors of San Francisco and Oakland to review the activities undertaken in response to the fractured girders at the Transbay Transit Center (TTC). Our review was initially divided into the following five phases:

1. Capacity of the temporary shoring system.
2. Sampling and testing plan for material from the fractured steel girders.
3. Cause of failure.
4. Impact of fractures on adjacent elements.
5. Repair of Fremont Street girders.

The results of the initial review may lead the panel to recommend other related investigations and analyses, which the panel may also subsequently review.

The purpose of this memo is to document the completion of our review of Phase 2, the TJPA plan for sampling and testing material from the fractured Fremont Street girders. The material sampling and testing was done to support analysis of the cause of the fractures and development of a repair plan. During the development of the plan, members of the PRP had a number of meetings with the TJPA project team, which includes the testing laboratory, engineer of record, contractor, and associated subcontractors, to review and discuss the plan. These meetings took place by conference call, as well as through in-person meetings at the TTC in San Francisco and at LPI, Inc. in New York. Our review started on October 15, 2018 with a meeting with the TJPA in San Francisco and site visit at the Transit Center, and was essentially completed with a visit of panel members to LPI, Inc. in New York on November 8, 2018.

Questions, concerns and recommendations from the PRP throughout this process were addressed by TJPA and reflected in the final material sampling and testing plan. That document, which forms the basis of our concurrence, is titled: "Transbay Transit Center Project – Girder Fracture Specimen Removal & Testing Protocol," dated 11.02.2018 Rev 4.

Our concurrence with the TJPA plan for sampling and testing material from the Fremont Street girders does not preclude future recommendations from the PRP for possible additional material sampling and testing, should we see the need for this as the investigation proceeds.

While the PRP has reviewed and concurs with the material sampling and testing plan, the responsibility for all aspects of the investigation of the fractured girders and resulting actions remains with the engineer of record.

Sincerely,

Michael D. Engelhardt, P.E., Ph.D.
Chair, Peer Review Panel

c. Members of PRP:
John Fisher
Brian Kozy
Thomas Sabol
Robert Shaw

March 15, 2019

Stephen Wolf, P.E.
Principal
Metropolitan Transportation Commission
Bay Area Metro Center
375 Beale Street, Suite 800
San Francisco, CA 94105

RE: Transbay Transit Center
Review of Designs for Repair of Fremont Street Girders and Retrofit of First Street Girders

Dear Stephen:

This Peer Review Panel (PRP) was assembled by MTC at the request of the mayors of San Francisco and Oakland to review the activities undertaken in response to the fractured girders at the Transbay Transit Center (TTC). Our review was initially divided into the following five phases:

1. Capacity of the temporary shoring systems.
2. Sampling and testing plan for material from the fractured steel girders.
3. Cause of failure.
4. Impact of fractures on adjacent elements.
5. Repair of Fremont Street girders.

The results of the initial review may lead the panel to recommend other related investigations and analyses, which the panel may also subsequently review.

The purpose of this memo is to document the completion of our review of Phase 5, repair of Fremont Street girders. The repair is meant to restore the structural capacity of the bottom flanges of the fractured tapered plate girders over Fremont Street (designated in the design drawings as TPG3), and consists of dressing requirements for the existing material and a new steel sandwich plate design bolted across the fractures.

This memo also documents the completion of our review for a related item, the design of the retrofit of First Street girders. Although the two TPG3 girders over First Street did not fracture and were subject to a different sequence of fabrication that substantially minimized that risk, the PRP concurs with TJPA's decision to further mitigate the risk and consequences of fracture by retrofitting the girders. The retrofit provides redundant capacity to the bottom flanges of the TPG3 girders over First Street. The design is similar to that at Fremont Street, with modifications accounting for the intact flange.

The review process included numerous online meetings as well as in-person meetings between Thornton Tomasetti and the PRP. The review extended over several months, starting with initial discussions of the design concepts and then continuing through evaluation of the detailed design.

Thornton Tomasetti addressed questions and comments from the PRP throughout this process. The PRP concurs with the design of the repair of the Fremont Street girders and the design of the retrofit of the First Street girders.

The basis of our concurrence for Fremont Street is:

- The final set of design drawings prepared by Thornton Tomasetti, dated January 28, 2019. The drawings are titled: "Fremont Street TPG3 Girders Repair Sections and Details," and are marked "Issued for Construction."
    - Sheets: S1-8401 to 8403.

The basis of our concurrence for First Street is the following documents:

- The final set of design drawings prepared by Thornton Tomasetti, dated February 22, 2019. The drawings are titled: "First Street TPG3 Girders Repairs and Details," and are marked "Issued for Construction."
    - Sheets: S1-8404 to 8406.
- Document: LA181690-PR-003 TTC TPG3 Hanger Blend Grinding Procedure - Rev 2A.
- Document: LA181690-PR-004 TTC TPG3 Hanger Needle Peening Procedure - Rev 1A.

While the PRP has reviewed and concurs with the design of the repair of the Fremont Street girders and the retrofit of the First Street girders, the responsibility for the design remains with the engineer of record.

Sincerely,

Michael D. Engelhardt, P.E., Ph.D.
Chair, Peer Review Panel

c. Members of PRP:
John Fisher
Brian Kozy
Thomas Sabol
Robert Shaw
Bill Mohr (consultant to PRP)

October 4th, 2018

Mr. Steve Heminger
Executive Director
Metropolitan Transportation Commission
Bay Area Metro Center
375 Beale Street
San Francisco, CA 94105

Dear Executive Director Heminger,

We write you today to express our continued concern over the situation at the Transbay Transit Center and to call on your agency to assist in evaluating the cause of the cracked beams and the plans to make repairs.

The Transbay Transit Center provides a crucial transportation link between our two cities. Once high-speed rail and Caltrain are brought to the terminal, it will be the transportation hub for our entire region. The Transit Center is too important to the future and the people of the Bay Area for there to be any uncertainty around its structural soundness.

There are many questions about what might have caused the beams to crack, who might be responsible, and how the beams will be repaired so that the Transit Center can reopen to the public. These questions must be answered quickly and the public needs to trust the answers.

We understand that the Transbay Joint Powers Authority (TJPA) is conducting its own analysis on the failures in order to develop a plan to make necessary repairs and we encourage that process to continue expeditiously. But we also believe that it is critical to the constituents of our cities and our region that there be confidence in the findings of that analysis. We believe that the only way to ensure this public confidence is by engaging an outside firm to review and verify any findings, and for this peer review to be managed by and produced for the Metropolitan Transportation Commission.

We respectfully urge the MTC to engage an outside firm as quickly as possible so that we can get down to the bottom of what happened with these beams, feel confident that the problem is isolated, and make the necessary repairs so that the Transbay Transit Center can serve the people of the Bay Area once again.

Sincerely,

London N. Breed
Mayor, City and County of San Francisco

Libby Schaaf
Mayor, City of Oakland