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GEOTECHNICAL RISK MANAGEMENT IN DESIGN-BUILD PROJECTS - A CASE STUDY ON SEISMIC RISKS

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Abstract: The Design-Build (DB) project delivery method has proven to speed the construction process of infrastructure projects since it permits construction to commence prior to the full completion of the design. Among the many risks entailed during DB projects, geotechnical risks feature prominently. This is because geotechnical engineers manage risks at a time when design-builders are expected to speed the project delivery. A common issue in the planning stage in DB projects is the amount of subsurface exploration and laboratory testing the owner needs to perform before issuance of the Request for Proposal (RFP). Therefore, there is a need to identify the current effective practices being employed to deliver DB projects while managing geotechnical risks. The objective of this study is to present how geotechnical risks are assessed and managed in DB infrastructure projects prior to contract award; providing recommendations for agencies to help manage geotechnical risks. To achieve this objective, the methodology adopted involved three steps: (1) a review of literature of how geotechnical risks are handled in DB projects, (2) a case study of two projects subject to geotechnical risks (the California Department of Transportation "I-15/I-215 Interchange Improvements-Devore" Project and the South Carolina Department of Transportation "Port Access Road" Project), and (3) a comparison between the two projects, including suggested recommendations. The case studies incorporated semi-structured interviews with each project's team, job site visits, and content analysis of both projects' documents.

1 Introduction

According to the American Society of Civil Engineers (ASCE), 2013 Report Card on America's Infrastructure, studies conducted on the deteriorating condition of the country's highways found that transportation agencies urgently need to locate ways to deliver projects related to infrastructure in superior, less costly, faster ways. With the pressing necessity to replace outdated, deteriorating infrastructure, especially highways and bridges, Design-Build (DB) project delivery method comes with many advantages to offer. This includes the way in which it speeds construction, reconstruction and rehabilitation of older, weaker infrastructure since it permits construction to commence prior to the full completion of the design. Clearly, among the many characteristics of DB projects, geotechnical matters play a key role. In fact, geotechnical design and construction requirements are essential to the success of any DB effort. Geotechnical engineers manages risks at a time when Design Builders are expected to speed project delivery. Thus, a common issue in the planning stage of all DB projects is the amount of subsurface exploration and laboratory testing for the owner to perform before releasing the Request for Proposal (RFP).

In dozens of states all over the nation, issues connected to geotechnical engineering have been reported by State Departments of Transportation (DOTs). Although DB works well in part because it often includes geotechnical investigation in its contractual agreements, it calls for many needs such as including solid communication on geotechnical issues among participants, careful review of site condition clauses, and extended review of geotechnical design information. The owner has to decide how much geotechnical investigation needs to be performed and included in the RFP to allow the proposers to consider the site conditions in their bids. Part of the collaboration seen before any award between the owner and the proposers includes provisions for Alternative Technical Concepts that allow proposers to submit improvements to the owner's requirements (Gransberg et al. 2014). This is in addition to the option for allowing proposers to perform additional subsurface exploration on their own before the contract is awarded. With many DOTs choosing the DB approach to accelerate project completion, the issue of geotechnical uncertainties and approval from DOTs on designs is often presented as a significant hurdle to commencement of construction. This becomes critical when faced with a project with high geotechnical risks. There is, thus, a need to identify the most successful methods currently employed in geotechnical risk management for DB highway projects. The objective of this paper is to present a case study analysis of how geotechnical risks are assessed and managed in DB infrastructure projects prior to contract award through two case studies with high seismic geotechnical risks.

2 Literature Review

NCHRP Synthesis 429 compiled the current practices used by DOTs for effective geotechnical study with regard to DB matters. It calls attention to the significance of subsurface investigation prior to the award of DB contracts and documents, as well as the state of geotechnical information in the solicitation documents and contracts for the execution of DB projects. Additionally, it outlines the critical role played by the DOT in DB projects. The issues associated with the added population stresses placed on highway structures, as well as the threat posed by earthquakes, has urgently necessitated more careful review of geotechnical risks (Gransberg and Loulakis 2012). Any project undertaken that involves public safety and design quality entails legal risks. Hatem (2010) observes that DB offers the chance to develop and enhance the improved contracting practices deployed for subsurface condition risk allocation and fair dispute resolution.

The need for greater flexibility for the design-builder is addressed in the RFP. The challenging 'art' of the RFP, as per Higbee (2002) is to assist the design-builder in reaching the desired performance objectives with as much room to maneuver as possible, thereby allowing the team to use creative and less costly methods. This pertains to pavements, bridge support foundations, and MSE walls. The challenge of geotechnical investigations is made clear through the great variety of state geotechnical evaluation criteria for design-builder qualifications, past experience, and investigations activities. No state has the same criteria as the other, and some have stricter requirements compared to others. It is due to that fact that thorough state surveys are necessary and call for establishing an 'average' among them to attain the most balanced, effective, complete methodology. It is also because of such state-to-state differences in geotechnical evaluation criteria that, as Gransberg and Gad (2014) note, the value of addressing geotechnical factors in DOT DB guidelines, as well as the encouragement of teaming with highly qualified geotechnical designers, and of including project management and field personnel with extensive geotechnical experience in the construction team, should be examined more closely.

The contractual end goal is to achieve reliability, clarity, and balance in risk allocation (Hatem, 2014), however different states have contrasting regulations administering risk allocation among the concerned parties, and some states have clearer laws than others. The recommendation is, therefore, to come up with uniform, reasonable and practical frameworks that everyone can live by (Hatem, 2014). A careful review of a recent Federal Highway Administration (FHWA) manual on tunnel design and construction outlined the vital considerations and recommendations necessary in coordinating all aspects of geotechnical risk management. However, geotechnical risks continue to be a hurdle when considering DB and the question of the appropriate level of geotechnical investigation necessary as pre-award questions are asked. The objective of this study is to investigate how geotechnical risks are assessed and managed prior to contract award in two DB mega-infrastructure projects associated with high geotechnical risks, specifically seismic risks. The study also provides recommendations for agencies presented with such risks on how to manage them.

3 Methodology

This effort demonstrates how geotechnical risks can be managed in relation to DB via a three-step methodology that includes (1) a review of literature to present a background of the problem (as covered earlier), (2) a case study of two projects subject to high geotechnical risks, specifically seismic risks, and (3) an analysis and comparison between the two projects. The two case studies included semi-structured interviews with each project team, job site visits, and content analysis of the project documents, including RFP, proposals submitted, risk registers, and geotechnical investigations conducted. This paper, therefore, examines design-builder's decisions with regard to geotechnical requirements closely associated with the procurement strategy of the DOT prior to the issuance of the RFP. Along with providing guidelines for managing geotechnical risks, it presents a viable approach for managing geotechnical risks on highway construction projects.

Case study methodology serves the purpose of this research as it handles the how question that is asked, (Yin 2003) specifically, how geotechnical risks are assessed in DB projects. The case study is a thorough research approach that explains, describes, illustrates, explores, and evaluates both qualitatively and quantitatively. According to Yin (2003), evidence for case studies comes from six sources: documents, archival records, interviews, direct observation, purchase at the end-all observation, and physical artifacts. Further, Yin asserts that data analysis requires the examining, categorizing, tabulating, and testing, both quantitatively and qualitatively, to understand what a certain study proposes. Reporting a case study involves bringing all results and findings to a closing point, tailored to the interests and level of knowledge of the target audience. Once the researcher selects the case study methodology, the most appropriate cases must be selected based on predefined criteria. In this study, two recent case studies were specifically chosen because they portray two large DB highway projects that are prone to high geotechnical risks. Based on the criteria, the case studies of the I-15/I-215 Interchange-Devore and the Port Access Road projects were selected. Yin's (2003) method of designing the case study influenced the research through the data collection process by setting a case study protocol to follow for conducting the case studies, including interviewing each project's team, job site visits, and content analysis of the documents with specific consideration to the geotechnical investigations.

4 Analysis and Results

This section will be divided into two parts based on the two case studies—the Devore and the Port Access Road projects, which, once analyzed, will then result in viable recommendations of managing geotechnical risks.

4.1 Case 1 – Caltrans: I-15/I-215 Interchange – San Bernardino, California (Devore)

4.1.1 General Agency and Project Information

The California Legislature has directed the Department of Transportation to assign 10 DB contracts for highway, bridge, or tunnel projects as part of a pilot effort under the new DB Demonstration Program. Contracts are awarded through low-bid or based on best value, as determined by the California Transportation Commission. The California Department of Transportation (Caltrans) District 8 is executing the Devore Project. District 8 is the largest of 12 statewide Caltrans districts and covers approximately 28,850 square miles of land. District 8 has performed over 20 DBBs, 1-5 CMRs, 6-10 DBs, and 10-20 Design-Sequencing projects.

The Devore Project case included a semi-structured interview which took place in District 8 in May 2016, with the project manager and lead engineer. In addition, a site visit was conducted in which more explanation of the site was provided along with the areas where issues evolved during construction. Content analysis of books 1, 2, and 3, technical reports, and the signed contract was conducted. The project is situated close to the community of Devore, California, in southwest San Bernardino County. The proposed project is to design and construct improvements to the I-15/I-215 interchange. The project would eliminate the existing lane reductions on I-15, reduce operational problems related to weaving trucks, and reduce operational deficiencies at the interchange including non-standard design features and correct arterial highway deficiencies. Project limits extend along I-15 from 0.8 mile south of the Glen Helen Parkway undercrossing to 1.4 miles north of Kenwood Avenue undercrossing and along I-215 from 1.2 miles south of the Devore Road overcrossing to the I-15 junction. In addition to being a commuting route, more than one million vehicles traveling through the Devore Interchange weekly and more than 21,000 trucks pass through daily. Funds for the project were provided by local, state, and federal sources at an initially estimated DB cost in 2012 dollars of $208 million, divided into a design cost of $14 million and a construction cost of $194 million, and increasing to $220 million. The type of contract employed was fixed-price DB. DB was chosen to reduce the delivery period, and thus cost, as well as to foster creativity. The project was initially calculated to run for 960 days, including design, finishing six months ahead of schedule over a period of 1,120 allowed working days. It was first advertised in March 2012, and was set to begin in fall 2012 and to be completed by fall 2016.

4.1.2 Procurement

The CTC approved the Project on July 1, 2010. The preliminary geotechnical investigations of the Project took over six months to complete, with another six months required for additional testing during 2010-11. The actual work specifications called for a month of planning, as well, and it took four months to close lanes and receive permits from property owners to scrutinize nearby private lanes. Caltrans used a two-phase procurement process to choose a DB contractor to deliver the Project. In the first phase, the Department determined which proposers were qualified to deliver the Project based on Statements of Qualifications (SOQ). A total of five companies were prequalified to participate in the RFP process. The RFP was issued in the second phase. The pre-qualification (RFQ) was released in July 2011, followed by the Request for Proposal (RFP) in February 2012. One-on-one meetings followed between proposers and the Department to discuss potential problems and clarifications concerning the RFP and the Proposer's ATCs, as appropriate. The Department issued the Notice to Perform (NTP) 1 to the design-builder for Limited Work, such as tree removal, clearing and grubbing, utility coordination, soil borings, temporary construction, or anything else specifically authorized by the Department. The NTP2 was issued to the design-builder by the Department for the remainder of the work. Substantial Completion was not to exceed 840 working days after execution of the DB Contract, with final acceptance within 120 working days following Substantial Completion.

4.1.3 Contractual Provisions and Status

4.1.3.1 Alternative Technical Concepts

The Department chose to employ the ATC process to permit creativity, flexibility, and to allow for design and construction to be finished at the same time, thus reducing conflicts and increasing speed and efficiency. This ultimately obtained the best value for the public. The contract allowed for spread footing ATCs which were received from non-winning proposers and were intended to offset geotechnical risks. The bidders submitted 10-12 ATCs, some of which were rejected, with the best ones selected for use to add the new bridge and establish a diamond-shape. Environmental risks had to be considered, as three acres of surrounding natural habitat were impacted since one ATC established a braided ramp at the Northbound I-215 Devore on-ramp and the Northbound to I-215 to Southbound I-15 Connector. The winning design-builder probably needed to re-evaluate its environmental document in terms of noise study and visual impact.

4.1.3.2 Utility Relocation

A description of how the risk of increased costs and delays associated with the Utility Work was communicated between the Department and the design-builder via the Change-Order process. Examples of this were concurrent delays, multiple relocations, Right of Way, and environmental compliance concerns. This pertained to the issuance of the Change Order to Contract Price. The Department would issue the Change Order to raise or lower the design-builder's Contract Price depending on circumstances of approval or rejection of the design-builder's proposed scope of work. A total of 36 Change Orders were issued during the execution of the Project. Two of the more important Change Orders concerned two retaining walls and the ultimate facility. The retaining walls represented a $3.5 million Change Order while the ultimate facility cost $9 million as a Change Order. Thus, the Project went $12.5 million above original cost. It should also be noted there was a savings of $1.5 million as a credit from the design-builder to the Department related to the AC price index.

4.1.3.3 Differing Site Conditions (DSC) Clause

Change Orders were issued by the Department to compensate the design-builder for added costs attributed to changes in the scope of the Work from Differing Site Conditions. Those conditions also included reference to geotechnical studies provided in the pre-award phase. The DSC was defined as follows:

> ***"Differing Site Conditions***
> *(a) subsurface or latent local conditions that differ from those reasonably assumed by the design-builder based on incorrect boring logs provided in Book 2 to the extent that correct boring logs would have resulted in accurate assumptions, or*
> *(b) physical conditions of a unique nature, contrasting materially from those normally found at the Site and generally known to be natural to the Work provided for in the Contract, notwithstanding in all cases that design-builder had no actual or constructive knowledge of such conditions as of Proposal Due Date.*
> *The foregoing definition shall not apply to Utilities, or Force Majeure events, nor shall it include any differences in groundwater depth or subsurface moisture content from that identified in the RFP. Clause (a) of this definition*

shall specifically exclude situations in which accurately reported boring data does not represent prevailing conditions in the area."

4.1.4 Geotechnical Investigations and Seismic Risk Management

This was the first DB project in the district. At the time of its 2008 conceptualization, many broader points had to be considered such as the local topography of Cajon Canyon, as well as any geologic hazards tied to that area like ground rupture. The project site is located in the earthquake-prone Southern California region within the influence of two fault systems (San Jacinto and San Andreas) that are considered to be potentially active. The owner anticipated that the project site would periodically experience ground acceleration due to small to moderate magnitude earthquakes. Seismicity, or the shaking of the ground from local and distant earthquakes, had to be examined. Ground water and soil corrosion, expansion, and erosion merited review, too. So did embankment settlement, slope stability, earth retention, sound walls, hazardous waste, and infiltration. All of this led to a recommendation for future geotechnical investigations.

Although this project was the first DB project in their district, the Agency knew that there was an inherent risk that needed to be dealt with that could not just be moved to the design-builder. Prior to advertising the project, geotechnical investigations were performed internally by the Department. This resulted in a Reconnaissance Report (RR), a Geotechnical Data Report (GDR), and a Preliminary Geotechnical Design Report (PGDR). Also provided in the request of the proposal was the Geographical Summary Report (GSR). There was no Final Geotechnical Design Report (GDR), Geotechnical Baseline Report (GBR), nor Geotechnical Interpretive Report (GIR) submitted by the Department before the project was advertised. The geotechnical report prepared by the owner during the preliminary engineering design identified the two potential faults within the project limits, as well. In addition, adequate subsurface exploration efforts, such as borings, were conducted at strategic locations to help to provide reasonable geotechnical parameters to the proposers. The Agency decided to do a fault trench study to determine and confirm the presence of a fault and to estimate the degree of fault rupture. The cost of the geotechnical investigation performed by the Department was $250,000, including fault rupture, with an additional $150,000 for preliminary site assessments for hazardous waste. The GDR budget was based around the costs of one preliminary materials report, one preliminary geotechnical report, 20 preliminary foundation reports, and the evaluation of existing data.

One main concern about geotechnical risk in DB projects is the lack of a comprehensive geotechnical design, meaning that geotechnical parameters and data available are not complete and identified during the procurement phase. In the interview with the project manager, he stated that in the case of the DB project, detailed geotechnical exploration and design parameters should be provided up front prior to the release of the RFP. Preliminary geotechnical reports are essential in identifying potential issues in a project. These reports are worth the time and effort invested so that bidders can know more about the project. Without that knowledge, design-builders are unlikely to bid, causing delays in the project's commencement. To reduce geotechnical risks, the preliminary geotechnical report was enhanced to include additional subsurface boring at strategic locations, including boring logs. A 10% contingency was included for all potential additional costs, meeting the Department standard of 5%. All geotechnical issues were covered by the contract. When there was a lack of data available to contractors during the contract proposal, it was difficult for a DB contractor to establish a competitive estimate without design certainty. The recommended approach was to perform detailed geotechnical exploration and to provide geotechnical design parameters up front prior to the release of the RFP. Geotechnical investigations represent a form of insurance that guarantees positive outcomes for DB projects. They engage DB enterprises in seismic design, metal reinforcement/corrosion protection, quality control/ quality assurance, notices to proceed, technical and cost proposals, question-and-answer process, and project follow-through. All of these are critical to the safe, successful execution of any DB project.

During the bidding phase, competing teams were allowed to request or obtain additional geotechnical information during the pre-award proposal regarding the additional borings self-performed by the Department. The design-builder had, prior to submitting the proposal, reviewed the preliminary boring logs provided by the Department, to the extent that the design-builder found it necessary or advisable. Activities included the inspection and examination of the Site and surrounding locations, as possible. The Devore Project was complex and presented diverse risks in design, construction, environmental compliance, and stakeholder coordination. The relocation of underground and overhead utilities presented potential dangers, as well, and influenced project scheduling and expenses. As stated earlier, there was also the matter of unforeseen subsurface conditions due to unexpectedly high groundwater levels or poorly sloped soils that might cave in or avalanche, as well as the possibility of the presence of contaminated substances at the work site. Any of these conditions were addressed through the due diligence performed by the design-builder early in the design process, and appropriate adjustments in design and construction were made.

It should be noted that the design-builder also contributed the needed manpower, machinery, and materiel to conduct subsurface surveillance, laboratory testing, engineering assessments, and reporting. Preliminary reporting included a Geotechnical Exploration Plan (GEP), Preliminary Foundation Reports (PFR) for each bridge, Preliminary Geotechnical Design Report (PGDR), and Preliminary Materials Reports (PMR). The design-builder performed field explorations, including bridge drillings, bridge borings, retaining wall borings, paving and completing borings, utilities locations, logging subsurface conditions, and excess soil cuttings. The design-builder provided final reports, as well, including Foundation Reports (FR) for bridges and retaining wall, Geotechnical Design Report (GDR), and Materials Reports (MR).

4.2 Case 2 – Port Access Road – Charleston County, South Carolina

4.2.1 General Agency and Project Information

The South Carolina Department of Transportation (SCDOT) has been increasingly using DB to deliver projects in cooperation with the FHWA. The Agency has procured more than 20 DB projects, the majority of which are on-going at the time the interview was performed for this study. SCDOT utilizes this and other alternative project delivery methods as a way to expedite delivery. This project was selected due to the high geotechnical risk involved. The project is located in a highly seismic location and the subsurface conditions consisted of liquefiable soils, soft compressive clays, high variability due to dipping stratum, and the potential for environmental contamination. The site is considered to have higher seismic acceleration than California. The scope of work, as described in the RFP (SCDOT 2016) is: *"a new roadway and structure Project to provide direct access between the proposed marine container terminal location on the former Navy Base and I-26 while maintaining adequate service for local, commuter, and commercial traffic. Included in the Project's purpose is the intent to safely integrate container terminal traffic with existing traffic; support local and regional planning policies and strategies; and minimizing adverse impacts on communities and the environment. The Project consists of the construction of a new fully directional interchange on I-26, a Bainbridge Connector Road, the extension of Stromboli Avenue and associated roadway improvements to surface streets to serve the proposed Naval Base Terminal (NBT) in Charleston County, South Carolina*."

4.2.2 Procurement

The project was awarded in 2016 for an estimated cost of $220,700,475. SCDOT used the following criteria to determine the project delivery method: size/estimated dollar value of the project, challenging ground conditions, environmental contamination, and potential for innovation. The agency is evaluating the use of a decision-making matrix for future projects and a DB Manual is currently under development.

4.2.3 Contractual Provisions and Status

4.2.3.1 Alternative Technical Concepts (ATCs)

ATCs were received for this project, but none based on geotechnical considerations. No ATCs were allowed for changing the seismic criteria in this project. As defined by the contract (SCDOT 2016):

> *"An Alternative Technical Concept (ATC) is a confidential request by a Proposer to modify a contract requirement, specifically for that Proposer, prior to the Proposal due date. The ATC process provides an opportunity for DB proposals to promote innovation, find the best solutions, and to maintain flexibility in the procurement process. ATC's are evaluated for approval or denial by SCDOT within the deadline set forth in the Milestone Schedule. In order to be approved, an ATC must be deemed, in SCDOT's sole discretion, to provide a Project that is "equal or better" on an overall basis than the Project would be without the proposed ATC. Concepts that simply delete scope, lower performance requirements, lower standards, conflict with environmental commitments, or reduce contract requirements are not acceptable as ATC's. SCDOT reserves the right in its sole discretion to reject any ATC. No ATC shall be included in the proposal unless approved by SCDOT in writing prior to the proposal submission deadline."*

4.2.3.2 Utility Relocation

SCDOT performed utility identification and included the information in the RFP. Wherever a utility has prior rights or significant time and coordination is required, SCDOT provides some coordination with utility owners before advertising or awarding a contract. A common practice is to notify utility owners or users before advertising a project as well. The reason for that is the fact that most claims that the agency receives are related to utilities.

4.2.3.3 Differing Site Condition (DSC) Clause

In this project's contract, DCS are defined as (SCDOT 2016):

> *"…. concealed or latent physical conditions at the Site that (i) materially differ from the conditions reasonably assumed to exist based on the information contained in the RFP, this Agreement and its Exhibits; or (ii) are of an unusual nature, differing materially from the conditions ordinarily encountered and generally recognized as inherent in the work. For this project, subsurface and geotechnical/geological conditions WILL NOT be considered as a Differing Site Condition."*

4.2.4 Geotechnical Investigations and Seismic Risk Management

Project geotechnical risks were perceived to be very significant, therefore, extensive geotechnical and environmental testing was completed prior to advertising the project to assess the potential risk. The project is located in a highly seismic area, and underground conditions consist of soil potential for liquefaction, soft compressive clays, variable conditions and dipping stratum, and the potential for environmental contamination. A total of about $1.2 million and more than 7000 man-hours were used for performing the geotechnical and environmental investigations in this project, around a third of the cost was due to deep boring for seismic consideration. There is interpretation of the data, though it doesn't specifically reference the DSC clause and is provided for information only. Interpretation of the data is used in part for developing the RFP to determine liquefaction potential and preliminary stability analysis.

The agency performed as much drilling as they could do, up to approximately 70% of what would have been done for a DBB. The alignment was narrowed down for this project, so the contractor did not have too much freedom to change it. Seismic parameters were provided to account for liquefaction or loss of shear capacity and slope stability. Also, an attempt to reduce overall risk was made by conducting relatively extensive geotechnical and environmental testing prior to issuing an RFP. Another measure was to include a specified dollar allowance in the RFP Agreement for testing and handling of hazardous materials (environmental contamination)

A very particular approach taken in this project is that DSC rights due to geotechnical/geological issues were eliminated from the contract. SCDOT had a very specific clause regarding the Compensation for Subsurface Hazardous Material that stated (SCDOT 2016):

> *"5. Contractor shall be responsible for the first $2,000,000 of Hazardous Materials Costs and shall include $2,000,000 for Hazardous Materials Cost as a part of its "Total Cost to Complete" in its Cost Proposal Bid Form. The $2,000,000 Hazardous Materials Costs shall be included in the Schedule of Values as a separate item. SCDOT will track Hazardous Materials Costs per the SCDOT Standard Specifications.*
> *6. SCDOT shall compensate Contractor for 100% of the total chargeable Pre-existing subsurface Hazardous Materials costs that exceed $2,000,000.*
> *7. Contractor shall take all reasonable steps to minimize generation of any such Hazardous Waste.*
> *8. Time Extensions: Contractor will not be entitled to an extension of Contract Time concerning any labor or activities connected to or associated with subsurface Hazardous Materials.*

Unexpected subsurface conditions appear to be the major risk factor in DB projects; particularly when conditions differ from those provided in GBRs or Data Reports. The Agency believes that projects in which there is significant risk of long-term settlement of embankments and/or structures, or any risks for which the Agency needs to retain control, are geotechnical factors in which the SCDOT would advise against the use of DB delivery method.

4.3 Case Studies Comparison and Discussion

Table 1 shows a comparison between the two projects. The contract for the Devore project allowed for spread footing ATCs, which were received from non-winning proposers intended to offset geotechnical risks. The contract included a DSC clause regarding geotechnical studies provided in the pre-award phase. There were no disputes with the contractor, nor any other party. There were contractual changes, but with no geotechnical component, during the execution of the Project regarding reduction of right-of-way acquisitions, facility accommodations, and pavement rehabilitation. This was the first project of its kind in the Devore area, and it was deemed a success. Although this project had many risks, the design-builder effectively managed them in partnership with the Department to ensure a successful project for all stakeholders. This was particularly impressive considering that the Project spanned a period of more than two years, from August 2013 to June 2016. The Devore Project stayed close to the original projected cost of $208 million, rising by approximately $12 million to $220 million by completion. This was to be expected since this was among the first DB projects in the state of California. It should also be noted that there was no harm to the environment since the Design Builder mitigated all the environmental risks associated with the execution of the project since the design-builder mitigated all the environmental risks associated with the execution of the project.

The Port Access Road Project, on the other hand, provides a different approach to managing the geotechnical risks. SCDOT provides interpretation of the subsurface information as a Geotechnical Baseline Report, but states in the contract that such information is for reference only and does not constitute any basis for DSC claims. In fact, SCDOT does not allow any geotechnical/geologically-related DSC claim according to the contract, which is a very particular approach that differs significantly from the way Caltrans handled the risk in the Devore Project. Despite this key difference, the analysis of both case studies shows that agencies subject to significant geotechnical risks tend to address them similarly by incorporating specific requirements or parameters in the contract and effectively retaining control of how the design is required to account for geotechnical-related criteria. Also, both agencies implemented a form of early contractor involvement by allowing proposers to submit confidential ATCs to improve the project, and to propose and perform additional subsurface exploration in the procurement phase. Such measures incentivize collaboration between the parties and constitute mitigation actions to reduce the geotechnical uncertainty.

Table 1. Devore vs. Port Access Road

Comparison point	**I-15/I-215 Interchange**	**Port Access Road**
Project Delivery Method and Contract Type	Fixed-price, lump-sum, DB	Fixed-price, lump-sum, DB
Project Location	Southern California	South Carolina
Issuance of RFQ	July 19, 2011	June 18, 2015
Issuance of Final RFP by Department to Prequalified Proposers	April, 2012	November 5, 2015
Award	November, 2012	2016
Construction Began	August, 2013	June 3, 2016
Project Completion	June, 2016	September 30, 2019 (Est.)
Initial Contract Amount	$208 million	$220.7 million
Final Project Cost	$220 million	under execution
Cost of Preliminary Geotechnical Investigations	$250k	$827k
Cost of Additional preliminary site assessments	$150k	N/A
Preliminary Geotechnical Reports	- Reconnaissance Report (RR) - Geotechnical Data Report (GDR) - Preliminary Geotechnical Design Report (PGDR). - Geographical Summary Report (GSR). - Fault Rupture Report	- Geotechnical Baseline Report (GBR).
Additional preliminary site assessments	- Hazardous waste	- Deep borings

	- Subsurface boring at strategic locations	- $2M allowance in the contract for hazardous material
Seismic Risks	- Highly seismic Southern California region within the influence of two fault system (San Jacinto and San Andreas). - Project site will periodically experience ground acceleration due to of small to moderate magnitude earthquakes.	- Highly seismic area. - Potential for liquefaction or loss of shear capacity and slope stability. - Underground conditions consist of soil potential for liquefaction, soft compressive clays, variable conditions and dipping stratum, and potential for environmental contamination.
Geotechnical Risk Investigations	- Seismic evaluation, provided preliminary boring logs, additional subsurface boring at strategic locations including boring logs, allowed for spread footing ATCs, and DSC Clause.	- Provided deep boring, as much boring as possible, seismic parameters were provided, DSC Clause.
Project Contractual Changes and Relocation	- Relocation accrued. - Relocation of underground and overhead utilities. • Reduction of the R/W. • Additional pavement rehabilitation. • No major geotechnical changes.	- Alignment of the site location was narrowed down which prevented the contractor of having the freedom to make significant changes in the alignment.

4.4 Conclusions

The objective of this paper is to investigate how geotechnical risks are assessed and managed prior to contract award in two DB mega-infrastructure projects associated with high geotechnical seismic risks; the Devore and the Port Success Road projects. The Devore Project demonstrated that preliminary geotechnical studies were central to the DB process in its many aspects. In fact, the geotechnical study proved invaluable under challenging conditions, such as those presented in the Devore scenario. Geotechnical investigations saved time, money, and effort in charting a course for success at Devore. We might keep in mind that the Devore area under consideration featured 20 miles of mountain pass at a 4% or better grade susceptible to flash flooding with a noteworthy big wash area. A better, immediate understanding of geotechnical investigations led to a substantial reduction in related risks in the future. However, it will only be through repeated use of the geotechnical approach that those advantages will become better known as knowledge of the field increases markedly. Therefore, the inescapable recommendation is to utilize geotechnical studies whenever possible, and without hesitation, in a situation like Devore's.

Since the Port Access Road project is still on-going, the results of the mitigation actions put in place by the owner in the contract cannot be totally concluded until the project is completed. The comparative analysis showed that, even though there are significant differences between the approaches adopted by each agency towards managing geotechnical risks in general, there is a meeting point when it comes to mitigating seismic related risks. Both agencies decided to include prescriptive requirements for seismic design in their contracts, even though the design is the responsibility of the contractor in DB. One way of accounting for that might be that the seismic events tend to have relatively high periods of return (i.e., the risk is less likely to manifest itself by means of an earthquake during construction), as compared to other geotechnical-related risks. Therefore, owners want to be sure the risk is accounted for according to their standards as a pre-award condition in the contract. This means, owners perform as much preliminary subsurface exploration and investigations as possible prior to contract award. It is important to note though the at the recommendations represented in this paper are based on the two case studies conducted, and could be thus further enhanced in future studies by including more cases with representative geotechnical risks.

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