MEETING SUMMARY

SHRP2 SERVICE LIFE DESIGN FOR BRIDGES (R19A) OREGON PEER EXCHANGE

TO	Raj Ailaney, Patricia Bush, Pam Hutton
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Background

The Federal Highway Administration (FHWA) in conjunction with the American Association of State Highway Transportation Officials (AASHTO) and the Transportation Research Board (TRB) have established the 2nd Strategic Highway Research Program (SHRP2) to address four focus areas – Safety, Renewal, Capacity, and Reliability. Project R19A – Service Life Design of Bridges, one of the Renewal projects, is an innovative technology approach being promoted to ensure that new more durable bridges are designed to remain operational for 100 years or more.

To assist agencies with advancing the implementation of Service Life Design, FHWA sponsored—and the Oregon Department of Transportation (ODOT) hosted—a peer exchange with the Washington Department of Transportation (WSDOT), South Dakota Department of Transportation (SDDOT), Wyoming Department of Transportation (WYDOT), and the R19A Subject Matter Expert (SME) team in Portland, Oregon, on July 25, 2018. The peer exchange provided a forum for participants to discuss and exchange ideas on Service Life Design.

Fifteen attendees participated in the peer exchange, including representatives from AASHTO, FHWA Headquarters, State representatives, and representatives from private engineering consulting firms. The peer exchange was formatted to provide a mix of presentations and facilitated roundtable discussions, as shown on the agenda in Appendix A. This structure provided attendees with several opportunities to collect information from their peers and examine different ways to implement Service Life Design. Representatives from Oregon shared their noteworthy practices and strategies as wells as the challenges and barriers they experienced in applying Service Life Design. The event began with opening remarks from AASHTO, FHWA, and ODOT, and was followed with the technical sessions and group discussions.

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Service Life Design - Key Peer Exchange Findings

Oregon, as an IAP Lead Adopter agency has embraced the concept of Service Life Design. They are in the process of developing standards to be used within the state. Those include developing environmental exposure zones based on the varying conditions in Oregon.

The Peer Exchange participating states, South Dakota, Washington, and Wyoming, did not have previous exposure to the concepts being implemented in R19A. They indicated that it would have been helpful to have been given a brief written overview of the project's purpose and direction prior to attending. This became an action item for the subsequent Peer Exchanges.

Oregon's R19A project, which prompted chloride investigation of in-service bridge decks, has evolved into State-wide testing during project development. This testing has successfully identified or ruled out degradation mechanisms on many structures. The service life design principles have avoided improper rehabilitation activities on many bridge decks. A contract is being administered to test another 42 bridges this summer in the expanded rock salt usage areas. Analysis of data from both projects will be used to develop a chloride exposure contour map in these areas. This exercise has given ODOT the tools to make better decisions on projects designed to extend the service life of our current inventory.

Oregon found that implementing the service life design procedures benefitted greatly from the financial assistance from SHRP2 and the technical assistance and tools developed by the SME team. They felt that without this support, they would not have accomplished what they did.

Peer Exchange Discussion Notes

Introduction

Pam Hutton (AASHTO) – Gave overview of the SHRP2 Program as documented in handout documents provided to participants. From publication *2017 Implementation Highlights - Advancing the State of the Practice*, identified $155 million in funding assistance, 340+ projects implemented, 300,000+ participants engaged, 12,300+ outreach activities, and 16,600+ hours of technical assistance rendered. Also discussed publication on *FHWA/AASHTO Implementation Assistance Program State Participation in Rounds 1-7*, which identified the 430 projects by product name and participating agency.

Raj Ailaney (FHWA) – Gave an overview of the SHRP2 Solutions for Bridges, which included the participating agencies for project R19A – Service Life Design of Bridges. Also discussed the deliverables being produced for R19A.

Bruce Johnson (Oregon DOT) – Gave an overview of ODOT's participation as a Lead Adopter Agency in R19A, and a brief history on the development of the concept of Service Life Design of Bridges which was initiated around the year 2000.

What is the service life limit definition? Is at beginning of corrosion initiation? Europe is defining it as beginning of initiation. Most owners recognize that we must operate bridges with some level of damage.

Neil – It is important to consider service life in conjunction with the level of maintenance and preservation actions the owner is prepared to tolerate. A 100-year service life with little or no maintenance is not a reasonable expectation.

Session 1 – Service Life Design Concepts

Mike Bartholomew of Jacobs and the SME Team presented an "Introduction to Service Life Design", which included the following key issues:

Definition of Service Life Design (SLD)

Goals of SLD

Past research and historical development of SLD

Introduced SLD design strategies

Deterioration modeling methods for concrete structures

Deterioration Limit States – depassivation (initiation of corrosion), cracking, spalling, loss of section (collapse)

Typical structures that have been designed for extended life

SHRP2 R19A program background and work focus areas, and

Tools developed by SME team to assist in the design for durability and service life

Discussion

Bruce – Has heard comments from states that we already do this. We have experience and see how our bridges perform over time and have enough information and knowledge to know where we need to use better rebar and increase cover. We know when we need to design more resistant concrete. Why do we need a design specification and have to perform calculations?

Mike – I have heard that too.

Neil – Has heard the same thing. Point is we have a collection of different methods to provide durability we are looking for. Every situation is different. This allows a rational way to taking a defense mechanism and applying in a way that makes sense. As we move forward and gain experience we can quantify how much better we will do with the corrosion resistant products. We need a rational way to make predictions. What we have now is empirical.

Raj – Those example projects – do they all have consideration as service life design as initiation?

Mike – Yes, I believe so.

Mike – In Canada on the Confederation Bridge on Prince Edward Island, they wired the bridge reinforcing steel for continuity to have the possibility to use cathodic protection in the future if necessary. They had a big symposium in Prince Edward Island to see how bridge had behaved after 10 years

Neil – They are quite actively monitoring the bridge and proactive with corrosion cells, etc.

Mike – One of their biggest issues is salt water. They made samples and placed in the same environment as the piers and have tested chloride ingress with time.

Neil – They have also paid attention to and are monitoring the progression of ice abrasion on bridge piers

Neil Cumming of COWI and the SME team presented on “Implementing Service Life Design for Concrete Structures”, which included the following key issues:

Introduced the International Federation of Structural Concrete (fib) Bulletin 34 – Model Code for Service Life Design

SLD Strategies – Avoidance, Deemed to Satisfy, and Full Probabilistic

Identified SLD Process

Define Environmental Exposure and Deterioration Mechanisms

Select Limit States

Determine Design Parameters – Materials, durability properties, cover dimensions

Develop Project Specifications – QC/QA process

Monitor Construction

Discussed process by example and showed use of Full Probabilistic tool

Specific material testing – NordTest NT Build 492

Andrew – Are you plugged in with David Trejo of OSU. He has done testing on critical chloride content of different types of steel reinforcement (galvanized, MMFX, various grades of stainless steel). It is very good research. I can get you his information. This is good research that has been corroborated.

Neil – That's what we need more of. Need to also know rate of corrosion once initiated. One issue I have with galvanized bar, is that there is no consensus on whether it works or how. If there is a holiday in galvanizing, and you have dissimilar metals you will burn through zinc quickly.

Andrew – I don't believe that this research covered coating or clad stainless bars. The results relate back to conventional black bar. We found from multiple suppliers that supplemental materials might differ with time (fly ash and slag).

Neil – in Canada, sources of fly ash make a big difference. There is, and will be, a shortage of fly ash in the future in some regions.

Bruce – Recently spoke with folks in Japan. They stopped using supplemental cementitious constituents that are added to mix. They strictly use blended cements where there is consistency in properties.

Neil –In many areas we don't have blended cement available, and in some cases fly ash is in short supply. Coal generating stations are being reduced.

Bruce – What do you do when your chloride migration coefficient test doesn't pass, and you have concrete in place? In Oregon we have gone away from production testing for tests 28 days or longer. We do a lot of prequalification testing, then no tests during construction unless for information.

Neil – We take the same approach. During construction, a test that doesn't pass is usually a problem with testing. Some agencies insist on tests being done.

Bruce – On bigger projects that have testing, what happens when test doesn't pass?

Neil – There is usually a lot of arm waving.

Bruce – Would you then ask designer to refine calculations or ask does that really see that amount of chloride?

Neil – That is rational but not the way model was intended to be used. The same holds true of measuring in situ cover thickness. What do you do if rebar cage shifted?

Bruce – We are in the same camp on galvanized rebar. We need in service testing. Time to initiation is long with galvanized rebar, but drop-off (propagation of corrosion) is fast.

Neil – references have been published on real decks where they used galvanized rebar. There are mixed results. It is not understood why. Modern products claim they are better. Is anyone still using epoxy coating?

Bruce – We do. We are trying to define different geographical areas. In coastal areas, we use stainless or glass fiber reinforced polymer (GFRP). In moderate areas, we are still using epoxy and getting reasonable service life. Where there is no chance of corrosion, we use black bar.

Group Discussion Topic – What does 100-yr SLD mean? (20 min)

Participants – what do you think it means?

- Limit States
- Main Structural Components
- Ancillary (Replaceable) Components

Mike - We've already discussed that the current procedures define service life is just up to initiation phase. What do people in the industry want to consider?

Neil – What we have seen in project documents is that the project must achieve 100 years without major maintenance. What is the definition of major maintenance? We have also seen paragraphs that state we must achieve 100 years without significant rehabilitation or repair. This is open to a lot of interpretation. One project specified a maximum 50% of surface area spalled. As an industry we need better definition on limit states.

Paul –The limit state should be when the bridge needs to be replaced in full. Bridge rail is an element that will need an update at least once over 100 yrs. Usually we are trying to justify when to replace. For decks, we expect routine maintenance on sealers and overlays but want to avoid demolition requiring replacing steel. For primary structural elements, we expect no maintenance. This would apply to foundations, caps, girders.

Mike –That's how things are looked at now. Expansion joints and bearings can be replaced. Those don't require the long life of everything else. We need better definition on what is considered major maintenance. If you just need to seal some cracks on a beam is that major maintenance?

Andrew – We need to have characterization of structural overlays because of the implications to traffic. We would consider that a major rehabilitation. If we go forward with the Columbia River Crossing, an overlay would affect everyone in the corridor. For something like that, we would consider a structural overlay as something that needs to be avoided.

Randy – We have 2 or 3 bridges left that are over 100 years old. They are functionally obsolete. They are single lanes with low posted values. Are these functionally in service 100 years from now? They don't see a lot of traffic.

Mike – Now materials are better. Is it practical to design a bridge for 100 years?

Randy – That depends on the size of bridge, and whether they are locally owned.

Neil – Other limit states besides durability may define the service like function, safety.

Bruce – NCHRP finished a research project that looked at a database of 36000 bridges. It studied reasons why bridges were taken out of service. Around 40% were because of condition reasons. Majority were due to functional reasons (number of lanes, vertical clearance). That's an important consideration, but don't know how to define it. I have been talking to planners. How do we come up with limit state on functional use of a bridge, so we focus service life design on those that we need to keep in service for 100 years. It's a complicated question related to land use and future development. But if it's more than half governed by functional reasons, we need to get a handle it.

Mike – What if a bridge only needs to be in use for 50 years, we design for that, then later find out we need it longer? The other scenario is spending too much on a bridge not needed for a long duration.

Neil – If we are looking at bridge 75 years old, when we fix it we want it to last another 75 years. We might have better technology in future, like expansion joints that last twice as long, bearings, paint coatings that never wear out.

Bruce – In terms of bridge decks, Washington looks at patched areas/delaminated areas. If the amount of repair reaches 2% of total area, then they start planning and programming major work.

Luong – First cycle of deck rehabilitation has been completed on delaminated areas. Most of our I-5 corridor is 50 years old, so we perform a 2nd cycle of deck rehabilitation on the patched areas.

Bruce – We did that on a major I-5 to I-84 ramp so it was the 2nd cycle. We are getting into that on our bridges also.

Joan – For 100-year service life design, we need to consider social, economic, life cycle cost issues, and integration into the region. It makes a lot of sense to incorporate planning, not just design our own bridge in a silo.

Paul – Traffic forecasts may help to address these functional issues.

Bruce - We are looking at probabilistic techniques for service life design. Why can't planners do that and get a range of probability to make some judgement? An open question on whether even possible. We need to challenge planning side of business.

Luong – Washington state spends a lot of money on decks. The next place to put money is on extending service life.

Session 2a – R19A Implementation Updates

Paul Strauser of ODOT presented Oregon's first project, on the "Design of Ochoco Creek Bridge". This was a replacement single span bridge in central Oregon to be investigated for service life. The goal was to follow the service life design process to evaluate the level of effort and the effectiveness of the design. Presentation content included:

- Defining exposure zones for bridge components
- Determination of environmental chloride loading
- Evaluation of standard ODOT mix designs for chloride migration coefficient durability properties
- Use of graphical design tools developed by SME team
- Monitoring of as-constructed chloride migration coefficient and cover depths

Raj – What tools were needed?

Paul – The graphical solutions were very helpful and very simple. Each ended up being customized by the site conditions. The SME team did the customization. Is there a way to have other tools that account for variations in temperature, the aging factor for the concrete mix? Production designers do not typically have a great understanding of how chloride profiles and permeability are tested and measured. Our preservation unit has invested some effort to this end, which is appreciated. If doing the service life design by myself, it would have been tough. The tools supplied were excellent. The SME team knowledge on testing side was a big piece to making this work.

Bruce – The chloride ingress equation can be automated in Excel.

Mike – Automation could be done. Anne-Marie with COWI created the curves, and they were checked with the full-probabilistic tool. Checking points on the curve was kind of trial and error by changing parameters individually to verify all points on each depth of cover curve.

Andrew - You would need to create a solver algorithm to accomplish this.

Neil – COWI uses a program (COMREL) that runs Monte Carlo simulation

Mike – Going the other way to create the curves is harder with the existing full-probabilistic tool.

Luong – How much time did the work take?

Paul –There was a lot of effort from Andrew and others. For me, a week would be plenty of time, for other people it would be more. In aggregate a fair amount of time was spent.

Andrew – Regarding NT Build 492 chloride migration coefficient test, if we were doing tests more often, we could approach internal materials lab to develop capability to perform the tests. It's not too difficult, but it is a time-consuming test. If done internally without having to ship samples, it could cut price in half knowing that lab overhead is already in place. For chloride testing which we do regularly, we have essentially paid for that equipment a couple times over. Cost to bridge by a factor of 3. Having own lab setup if doing regularly can save a lot of money.

Mike – Iowa and VA have bought equipment

Andrew – The setup is not expensive. It's all about labor cost if we are going to do these tests on a continual basis.

Raj – NT Build 443, is that different from NT Build 492?

Neil – NT Build 443 is a ponding test, NT 492 is an electrical migration test, so they are two different tests.

Mike – Typically you don't use the full NT Build 443 ponding test. The ponding tests are performed on new concrete lab test samples exposed to accelerated chloride loading, often for 56 days. We just want to core existing bridge decks that have already been exposed to chlorides, then develop chloride profiles representing the actual environmental exposure. (The only portions of the NT Build 443 test that would be used are the section referencing the acid soluble chloride measurements done in accordance with NT Build 208, and Appendix A describing how to develop profiles.)

Andrew – The test we used wasn't NT Build 443. It was ASTM C1152 or AASHTO T260 which are essentially the same and correspond to NT Build 208. The chloride tests for Ochoco Creek Bridge were done by Tinnea & Associates. They used a different test that they correlated to the ASTM C1152 test and we deemed it had acceptable correlation. The results showed a good profile. Tinnea claimed it was faster than the acid soluble chloride test (ASTM C1152), and it eliminates using nitric acid. They test for change in potential. The test, "An Alternative Potentiometric Method for Determining Chloride Content in Concrete Samples from Reinforced-Concrete Bridges, is from Virginia Transportation Research Council, and published in 2002. Tinnea had been using it for years rather than the nitric acid test.

Paul – NT Build 492 gives chloride migration for new concrete. Cores were taken on existing structure to produce chlorides at given depths. That was how we produced the points for chloride profile fit.

Joan – Is there an existing bridge in place? How do you quantify chloride demand?

Paul – We used existing structure because alignment would be same and same de-icing maintenance. So, it would provide what chloride loading to expect.

Joan – What is done for a new bridge with new alignment?

Paul – We would be extrapolating from others in state with similar environmental conditions.

Joan – Would it then be possible to do something standardized with this type of environment and traffic to reduce level of effort?

Neil – I've run into this. We need a number to use in the model. We can either obtain it from existing structure or measure something reasonably representative. It might be conservative and penalizing.

Paul – Designers are consumed by current work. ODOT has tried to standardize detailing practices by region. Here we are looking closer at where those are. Is there a distance from coast or elevation? We have some areas in Siskiyous with lots of deck issues. Can look at inventory and using quantitative tools to hone in on a solution.

Eric – Have you looked at changing demand level?

Bruce – On a statewide basis we have asked crews to monitor liquid magnesium chloride and rock salt application. We are not getting lots of cooperation on actual measurements. But they will give us generalization of application rates.

Eric - That seems like it can fit in political conversations.

Bruce –There are other more political reasons on how we use salt and deicing.

Paul – if you talk to maintenance staff, their minds are shaped by years that were really bad. 2017 was bad. Last year we hardly did anything. It's hard to plot out what the loading is year to year.

Neil – Have you seen any increase in scaling where you are using the magnesium chloride?

Bruce – We understand it is detrimental to steel. We don't have evidence now, but it takes a long time to affect concrete.

Neil – References show that chloride ions are more mobile with magnesium chloride. See NCHRP 577.

Bruce – We don't have data to show that. We expect some detrimental impacts to our concrete surfaces but haven't detected it yet with mag chloride.

Paul – We have some bridges with prestressed concrete girders right at the overhang. Those end up needing maintenance and sealant. There is minor delamination happening along those beams.

Andrew Blower of ODOT presented a second project on "Testing and Evaluation of Existing Bridge Decks for Chloride Concentration". Presentation content included:

- Use of Service Life Design principles
- History of De-icing Usage in Oregon
- Sampling and Testing Methods
- Case Studies
- Rehabilitation Approaches including Overlays
- Summary, Conclusion, and Future Work

Raj – Do the overlays have the same coefficient as concrete?

Andrew – These are thin epoxy-based cement. The diffusion coefficient is almost zero.

Neil – You have to be a little careful doing electrical tests on polymer modified concrete. It's an insulator, so not sure the test is relevant. I am curious how silica fume overlays are performing. Are there any cracking problems?

Andrew – Yes there are cracking problems that are variable by curing placement. Some have shrinkage cracks. Some are beautiful.

Bruce – Some crack quite a bit. But they seem to wear well even though there are cracks, unless something goes wrong with surface preparation.

Neil –The nature of the corrosion in silica fume decks is different than in conventional decks. Resistivity of silica fume concrete is very much higher. Corrosion cells at the root of cracks is concentrated. We don't see the broad type of planar delaminations in silica fume as you do in conventional concrete.

Andrew – We use epoxy-based sealer flood coats to combat cracks in concrete of any age. This seals cracks well and we are proactive about that preservation activity.

Neil – You should forget about silica fume and spend the money on shrinkage reducing admixture and conventional – high fly ash mixes.

Paul – We've been making that change anytime there is "class 2" full depth of below top mat of steel. We've used ½" aggregate a few times because of the depth of overlay. Designers are eager to use PPC because it's quick to lay down, but we are not doing the things required to show it will last. In region 4, anytime we program a PPC overlay, we take cores early in the process to show there is no chloride issue that will cause concrete to delaminate and take overlay with it.

Andrew – The original goal was to map entire state and we are still working towards that goal. We want to identify high chloride usage areas and try to get those wearing surfaces on preemptively on a clean deck surface. The goal is to get a contour map of the state to make decisions about where we want to add more protection (MMFX or epoxy coated reinforcing, or epoxy-based wearing surface). We are going to replace decks on the two bridges at Siskiyou summit. Because of changes and rock salt use, we are putting PPC overlays on those after the decks have time to go through early age cracking process. In that area it is most definitely appropriate. We don't want to be replacing these decks as it is huge to freight mobility to have those traffic control plans.

Raj – Have you considered putting overlays on as part of initial construction?

Andrew – Yes, that is what we are doing on Siskiyou. We originally wanted to see a full year of thermal cycling first, but that appears to be over-kill and we will wait 3 months. National Bridge Preservation Partnership (NBPP) is putting together a design guide on how to go about chloride testing on both project and network level. This will be put it out quickly. Powder vs core sampling. Need to collaborate to come up with recommendations. Come up with frequency of network level testing, whether to do network level testing. Lay out ideas for asset management and owner can decide.

Mike – Iowa did some testing outside of SHRP2. Is Iowa involved?

Andrew – Yes.

Mike – They have consistent results on two corridors. This would be good data for NBPP to obtain.

Andrew – We find that too. But in the Columbia Gorge we can get wildly different results.

Group Discussion Topic – Challenges of Durability Testing (25 min)

- Chloride Profiling (powder samples vs. cores)
- Concrete resistance to chlorides

Bruce – Chloride profiling costs money, and needs traffic control, a dedicated crew, and lab support. For decades we managed our bridge deck overlay program without chloride information. So far, we believe that even though it costs money, our conclusion is that it's worth it because we have had some poor performance when we didn't have the information. Having chloride data is going to help us make better decisions. We plan to continue program.

Mike- Are other states doing similar programs?

Randy – In Wyoming we are trying to do surveys early in design stage. I'm not involved in lab activity. Don't think they are doing chloride profiling.

Steven – In South Dakota we aren't doing chloride profiling yet. We know qualitatively how much deicing is being used.

Luong – For Washington it is case by case. So far, we don't have chloride program to do testing.

Steven – We have more freeze thaw and deicing salt.

Andrew – To speak to cost, I don't track expenditures but have done it a couple of times to get an idea. Cost depends on traffic control. Stopping the Banfield Interchange is $20k-$30k just there. On average with traffic control, the single lane average cost to do an entire set of tests is $7k-$10k. This is 4 to 6 cores on a structure. Today we've spent somewhere on the order of $300k but have saved between $2M and $3M dollars in eliminating incorrect overlay work. It's confirmed we are doing the right thing. Even if it doesn't change your mind on a solution, it gives you peace of mind after spending millions of dollars. It is absolutely worth it on big structures. On smaller structures, we might want to take it case by case.

Paul – The John Day River Bridge had a PPC overlay installed. Due to the length of the structure, this was a high dollar investment. Shortly after completion of the work, several large areas delaminated. Having quantifiable chloride data on hand allowed us to speak with a fair level confidence that deck reinforcement was not corroding and that these areas were likely present prior to construction. It turned out this was a workmanship issue and was readily resolved.

Randy –What frequency would you test on a network basis?

Andrew – We are collaborating in NBPP to set up guidance. It will be up to states to set boundaries. It depends on total number of bridges, their age, high ADT, or areas that use lots of salt, or studded tires.

Paul – We have been diligent about it at project level. That's the easiest place to start.

Session 2b – R19A Implementation Updates

Craig Shike of ODOT presented a third project on "ODOT's Sample Design Build Specifications. The goal of this project was to create a sample specification for durability design that could be used on a major project such as the Columbia River Crossing. Presentation content included:

- Specification Language (Imperative Mood vs. Indicative Mood)
- Service Life Definitions
- Design Parameters Specified by Owner
- Durability Design Strategies to be Used
- Length of Service Life of Major and Replaceable Components
- Durability Testing Requirements

Joan – Will these be a standard specification?

Craig – No, this was developed for a currently dead project

Bruce – The specification is included in the ODOT R19A final report – also wrote a summary report from individual workshop.

Mike – The report is on the AASHTO SHRP2 R19A website. Everything we have done is on or will be put on the website.

Mike – birth certificate for structure. Then continue it throughout life of structure. Recording cores, maintenance plan.

Bruce – You did an example Birth Certificate for the Ochoco Creek Bridge. Is it on website?

Mike – I am still working on that one. The design for Ochoco was well over and above what was needed. I re-did the calculations for it by increasing the surface chloride loading. It now shows a 100-year service life with double the chloride loading.

Andrew – We are fortunate that we have relatively low chloride loadings compared to rest of the U.S. In a bridge condition report on the 56 bridges we tested, we identified 12 that had issues, and 2 were getting a deck replacement. Considering rate of testing, it is significant. I can only imagine what other states look like.

Craig – The sample specification also requires hardened concrete cover dimension testing.

Group Discussion - Challenges of Alternative Delivery projects

- **Request for proposal requirements**

Neil – Consider and contrast several scenarios:

In the design-bid-build approach, there is a shared objective for the bridge to last 100 years. There is collaboration between designer and owner/client and it works out.

In the design-build arena, the client is usually the design-builder. The client's objective is to win the job. Cost to improving durability is now an obstacle. In the construction and testing phase of design build model, the constructor will gut the specifications in terms of testing frequency, etc. From designer's point of view, it is a challenge to manage that to get a durable structure while keeping client happy.

In the design-build-finance-operate model, the constructor has to maintain bridge for $\geq$30 years. The new objective is to minimize handback risk. After 30 year mark the client doesn't care anymore. Important for owners to understand the objectives.

Andrew – Would you be a proponent for 3rd party quality assurance plan hired by owner?

Neil – Conceptually yes, but everyone must understand what is QA vs QC. My definition is QA is making sure QC is working as it supposed to. A lot of people define it differently.

Andrew – Our specification section had to define that role because it got so muddy. It got to the point that the inspector was doing QC not QA.

Neil – That happens a lot, where QA takes over QC. Contracts are not generally set up that way. You've got to make sure QC process is administratively separate from construction process.

Eric – I worked on a project where they were married. If you ask them they were separate.

Mike – Some of the things we see in RFPs are statements that you should design the bridge for 100 years with no other requirements. Others are specific and say you use a program like Stadium, which Is directing something not verifiable. There are issues in turning all service life design decisions over to a design-build team. Specifications need to be robust to cover issues.

Neil – I think the handback will be a goldmine for lawyers.

Paul – Does CMGC play a role?

Neil- I'm accustomed to a prequalification process for bidders. Typically, the consortia team puts forth qualifications, then they put in a bid, and the low bid wins. The problem with a qualification-based concept is that it boils down to low price anyway. If you only have 35% on methodology, the spread is typically ~27-35. If 20% on cost the spread is 0-20. Numbers games. Properly done you choose based on qualifications first then choose the lowest bid.

Pam – That's how we select consultants and CMGC

Neil – An informed owner will have a pretty good idea of what a design contract should cost.

Pam – We worked on a big CMGC project with several bridges in two interchanges. It included design work. I don't know if there was a service life design criteria requirement.

Paul – It seems like a good way for contractor to help inform decisions.

Neil – I've seen it where the owner will hire senior construction people to help with constructability and costing.

Pam – That's kind of like CMGC, but they would hire separate firm to inform the owner. It seems like this would fit perfect in that model.

Paul – You would just have to pony up the money.

Pam – Then you would make informed decisions.

Mike – Then the price would come after.

Pam – But qualifications are how you hire the contractor and partner consultant.

Paul – It fixes the issue of specifications being gutted.

Andrew- They would want some compensation in case the project got shut down.

Eric – You will pay a premium because contractor will be only bidder.

Pam – But you have beauty negotiating that with CMGC.

Mike – Eric, how do you think service life design on Sellwood CMGC would have worked?

Eric – We would have had challenges because just enforcing the specification was a challenge.

Mike Bartholomew of Jacobs and SME team presented on "SHRP2 R19A Participation from Other Agencies". Presentation content included:

Identification of Lead Adopter Agencies and Project Leads

Work Plans for Each Agency

FHWA Central Federal Lands – Service Life Design of new bridge along coast in Hawaii

Iowa DOT – ASTM A1010 Structural Steel in de-icing environment, Twin structure replacement in de-icing environment, Thin polymer overlays

Maine DOT – Replacement of the Beals Island Bridge along the coast

Pennsylvania DOT – Testing PennDOT standard concrete classes for Chloride Migration Coefficient

Virginia DOT – Testing VDOT standard concrete classes for Chloride Migration Coefficient, Developing environmental load parameters for de-icing chlorides

Lessons Learned

R19A Next Steps

Bruce – What states are performing service life designs on real projects?

Mike - Oregon, Hawaii, Iowa, and Maine. But many are using the avoidance of deterioration approach.

Bruce – For the R19A products so far, there are not a lot of full examples of service life design. Did you say you were working on doing one yourself?

Mike – Yes, we are doing two new ones. One is already complete and turned into a presentation which was delivered at the International Bridge Conference (IBC) in Washington, DC on June 14. It was a worked example for a steel bridge located in New York City where we looked at coating life.

Eric – Does it look at weathering steel and section loss?

Mike – We evaluated section loss on the piles. There are some guidelines for that. We looked at coating system guidelines from the National Association of Corrosion Engineers (NACE), Paper 7422. It covers approximately 50 combinations of 1, 2, and 3 coat systems, and how long they are predicted to last, based on data derived from contractors, fabricators, coating specialists, and owners. The report highlights when to perform spot touch up, maintenance overcoat, and complete removal and re-paint. We will do another example of a bridge in a coastal marine environment in the southeast US. We will also develop calculations for the deterministic method using load and resistance factors (also called the partial factor method).

Luong – Does your example cover substructure?

Mike – Yes, we have included substructure.

Paul – We have recently been doing pile coatings for steel sections in salt water. A lot of pile section is there for driving and not needed for strength. So, when you are doing this down through substructure, does it go into that level of detail?

Mike – We looked at what design was needed for strength. In this case we investigated sulfate exposure. We assumed piles were designed to structural capacity and added steel to account for corrosion allowance. We investigated the Eurocode and Florida DOT Structures Design Guidelines recommendations. We collected different documents because there are no standard documents in the US.

Raj – Bruce, you mentioned that ODOT uses all kinds of rebar (black, stainless, etc.). Have you done any cross analyses to come up with that decision?

Bruce – We have not performed a formal life cycle cost analysis. Intuitively we believe the investing of stainless steel for coastal environment is appropriate. But it is on to do list. The same question could be answered about how we invest in cathodic protection systems. Is that cost effective over the life of the structure? We started this 20 years ago to help convince us we were doing the right thing. We've collected information, but we haven't published.

Bruce Johnson of ODOT presented on the "NCHRP 12-108 – Guide Specification for Service Life Design of Highway Bridges". Presentation content included:

Project Objective – New AASHTO Guide Specification

Overview of Specification Sections

Three-Tiered Methodology

Deemed to Satisfy

Avoidance

Full Probabilistic Calibrated Deemed to Satisfy for Chloride-Induced Corrosion

Service Life Categories (Normal 75-years, Enhanced 100-years, Maximum 150-years)

Exposure Zones

Development of Concrete Cover Table

Protection Strategies for Structural Steel

Raj – I'm wondering if we should have this or more detailed presentation at next peer exchanges because lots of other states will be there.

Bruce – NCHRP is planning to do a webinar. We should arrange for TRB presentations. Maybe post a draft on the SHRP2 webpage. Would like to get as many people as possible to get feedback, then conclusions on in service monitoring and rehabilitation projects.

Raj – Will need what ODOT is doing in future as part of final report.

Session 3 – Group Discussion Topics

Everyone took time to fill out service life design survey questions, then discussed the survey questions with groups.

Pam – As a result of today's workshop, will you take this back to your agencies?

Yes, from Wyoming, South Dakota, WSDOT

WSDOT – Will consider for future projects

Pam – Could AASHTO or FHWA do anything to facilitate you adopting this in your agencies? No response

Pam – If FHWA were able to provide you with additional technical assistance, would you need leadership to buy in?

Luong – Someone high up would need to make decision and buy into it.

Pam – How high up? State Engineer, or Chief Bridge Engineer?

Luong – Yes, both those levels.

Pam – We have designed bridges for 50 years, but many have stayed in place 75 or 100 years. I don't know if it is a huge leap or not.

Pam – It's important to take into consideration total life cycle cost.

Luong – It will take a decision at high level to pay for it.

Pam – This product started as being 100-year life cycle service design or so. We took 100 years out of the title purposely because it is a decision each agency needs to make themselves. Practical design gets into that issue because it costs a lot to rehab a bridge in general. Some thoughts that we would like to hear

Craig – Our Columbia River Bridge from 1917 is still operating. We've put a lot of maintenance into making it last. It had 50 year design life, but we're making it last 100 yrs. Most of the bridges we replace are likely due to

functional issues, but it's hard to get good data. Any way we can add to the knowledge to get more confidence in these methods is going to help have better life cycle analysis and make case to upper management.

Neil – One thing I see happening with this concept is we are talking about 100-year service life with little or no maintenance. The missing element is the incremental cost to achieve that. Going forward we need to bring that back into analysis.

Bruce – I agree for future work. There's a lack of documentation of the value of doing service life design. What are we getting for it?

Neil – What is that incremental cost to achieve the service life and is there a more effective way of spending money?

Bruce – If service life design is not appropriate at a site, then you want to save that cost. We can tell how much it costs for stainless steel or GFRP rebar on a bridge because we have done it. So, we know what that incremental cost is for certain types of design. If you use regular rebar and all you are doing is quantifying certain types of concrete, you could try to quantify adding fly ash or silica fume but we haven't done that.

Mike – The Birth Certificate I mentioned earlier is intended to start to document that type of information.

Neil – Twenty years ago, the buzz was life cycle cost analysis. We have gone beyond that. Now it's not only cost, it's a traffic issue.

Bruce – What could FHWA do to further encourage service life design? In terms of doing it in Oregon, if we didn't have seed money to do testing and especially if we didn't have access to subject matter experts, we would not have accomplished what we did.

Pam – I suspected that. We all have lots of work with limited resources. To stop regular production and come up to speed on the new stuff can be daunting.

Pam – On survey question 7, how did you implement the service life design? (directed to WSDOT)

Luong and Nicholas– The project was the Alaskan Way Viaduct replacement of the double decked bridge with a tunnel. The project was raised up to highest importance level as replacement would be so expensive. It is a design build project.

Craig – We need ways to speed things up. Recent example was Abernathy widening. Once that is done we can't close. We can identify those types of bridges due to mobility problems. That might be 10% or more of your inventory. We should start with those bridges and then it will get more routine and then spread to less critical bridges.

Pam – We're not going to reconstruct bridges like we used to. It won't be publicly acceptable

Mike – Will you be able to close lanes on that bridge for some maintenance?

Craig – We are behind on inspections because we can't close bridges. It's getting harder to make that case all that time. If there is a means to do it without closing then that's what we have to do.

Bruce – We can close a lane at night.

Pam – The premise on renewal is build it and stay out.

Conclusion – The state that's sponsoring can answer all questions. Invited states probably can't answer too many of them. Most of the peer exchanges.

Pam – We need to generate more conversation.

Bruce – If guests have some level of advance information about the content of the Peer Exchange they would be better prepared to participate.

Mike – We can develop something that is brief enough that they will read it.

Pam – If you had had a one-page summary, would you have had time to sit down with your State Bridge Engineer to discuss philosophy, then come here and take back information to the State Bridge Engineer?

Steven – Yes.

Pam – What would have made this more beneficial for you to help prepare for today?

Luong – Yes, I think so. Just the list of questions to think about before you come and discuss with your State Bridge Engineer.

Joan – There is ACEC WSDOT bridge committee meeting every other month. We could talk about this. I don't work for the state, but WSDOT pushes practical design. Seems to me that this can be part of practical design. Then awareness and importance can be higher.

Pam – I agree. It depends on how you look at it. This can be a higher upfront cost.

Randy – Our state tends to be more reactive. We are doing some standard things that can be considered service life design like epoxy, and coating systems, but it's kind of a new concept to us. It will take time but will catch on.

Eric – Certainly if the service life guide specification comes out it will catch on.

Mike – Some of these items discussed will go with future topics for next peer exchanges.

- **Design Issues – How is concrete cracking taken into account?**

  Neil – Whenever you talk to somebody about service life prediction they throw up their hands and say it only works for concrete between the cracks. Cracking, construction joints, local defects, and other local anomalies will not reduce overall service life of structures. You are not going to tear it down 5 years earlier due to this, but it will increase maintenance. You've got to keep it in the right context. In terms of cracking, my approach is that cracking happens, deal with it. You design for crack control, you build for crack control and you maintain for crack control.

  Mike – The procedure that was developed for *fib* Bulletin 34, Model Code for Service Life Design, looks at how chloride diffusion coefficient changes with time. *fib* developed the procedure for structures that have been in service for many years. The procedure uses new data on uncracked cylinders and correlates it to chloride profiles for concrete cores that were cracked. There is a limitation of 0.012 inches in *fib* for crack width. If concrete has that small of a crack it can be treated as uncracked. Some people debate whether crack width should be smaller. I hear it all the time that you can't use cracked concrete to satisfy conditions, but believe you can.

  Eric – Is 0.012 inches the same crack width as in the ACI 318 design standard?

  Neil – Corrosion can happen at a smaller crack width than the codes allow. The more important parameter is crack density (i.e. lineal meters of crack length per square meter of deck area). I investigated that a few years ago but found little published information.

  Mike – *fib* has established a new task group to investigate chloride diffusion versus crack density.

  Neil – Others have tried that and their conclusion is there is no correlation.

- **Construction – How can we verify the durability properties specified in design are achieved during construction?**

  Mike – We have talked about this today as being important, but what do we do ensure it?

  Bruce –Production testing can be performed for information for further use in the structure. Can't you just test during production?

Neil – Once you do pre-qualification, you can manage the batching tolerances during production. If you achieve batching tolerances from ASTM, 80 – 90% of problems go away. It's best to do the QC before it is placed.

Mike – You don't want to allow water to be put in at the site, as water/cement ratio plays a large part in the chloride migration coefficient.

Paul – Having worked for the construction office, I am seeing concrete in a new light. There is a 90-minute threshold for batch to placement. Lots of times we use Delvo retarder. Do admixtures affect the durability?

Mike – You don't want to use corrosion inhibitor in the chloride migration test.

Neil – Inhibitor will affect set time. Then you have to add more Delvo. The 90-minute threshold is often written in codes and specs, but it depends on temperature and admixture system.

Paul – Coincidentally the maximum temperature is also 90 degrees. If they add accelerant on site, water is then add water.

Eric – This is not a material property, but would scanning of rebar after deck is hardened be used as a birth certificate information or would the contractor get penalized if under tolerance?

Mike – There is a German standard for measuring cover in hardened concrete. It allows a few out of tolerance measurements, but if over a certain percentage, corrective action may have to be taken.

Neil – The rebar cover used in the time to corrosion calculation is based on mean value and standard deviation of cover thickness. Note that these parameters are different than the allowable placement tolerance in most standard specifications. When an area of low cover is found, perform enough sampling to get statistical analysis to determine whether there's a problem.

Mike – That's the approach taken for Ochoco Creek Bridge, but readings got lost. There was more than adequate cover, at least 3 inches. The German standard has a statistical means of accepting or rejecting. The contractor must mitigate the problem or potentially pay a penalty.

Eric – Is this the approach in Craig's specification?

Craig – Yes.

Neil – If you have a robust QC process, all those problems hopefully go away. But you will get deviations.

Luong- Is there an equation for the tolerance?

Neil – Typical to use a 3-test rolling average of concrete tests like what is used for design strength.

Luong – Would you include this in the specifications? Or if you designed for 100 years, then found some deficiency, would you reduce the service life to 98 years?

Mike – You can do that in a birth certificate. You can use the actual as-built properties to determine a new service life. Testing can verify properties that are either above or below what was designed. It will give an indication if you have a potential problem in the future. The birth certificate is used to project end of life service.

- **In-Service – How can a regular monitoring plan be implemented to verify that performance matches design intent?**

  Mike – This is where it is envisioned that on a 10 or 20-year interval you would do some chloride profile monitoring of a structure to compare actual with what was predicted. At the *fib* committee meeting, we discussed initial chloride profile monitoring at 10 years to see if actual is close to predictions, then set up a plan for 20-year testing intervals to evaluate structure behavior.

Randy – Then would you compare that with routine inspection data?

Mike – Yes, but am not sure how you would use routine visual data.

Randy – The ultimate judgement is to see no cracking or issues.

Neil – You want to see chloride penetration profiles and compare to what was predicted during design.

Andrew – I don't see agencies doing that besides for academic purposes.

Neil- I have seen this monitoring built into requirements for handback on design-build-operate projects. Then at handback you can compare condition to prediction. If you don't have it in the contract, then monitoring doesn't happen.

Mike- It doesn't make much sense to design for service life then not monitor it. If you perform monitoring, you might discover the structure has only 80 years of service life. Then can make alternative plans before the structure starts serious deterioration.

Luong- Can you get credit back?

Mike – You can try.

Joan – If the design-build-operate maintenance contract is for 30 years, the contractor is motivated to achieve 30 years but not for 100 years.

Neil – The contractor determines the risk for handback at 30 years.

Ray – They want the degradation curve to drop off at 30 years (joking).

- **What Organizational Structures Are Required to Successfully Achieve Longer Lasting Bridges?**

Craig – We have a lack of money.

Bruce –That forces us to look at service life. We have design, inspection, and preservation units. In the preservation unit we have people that have had training. We had to go to someone who already knew corrosion and testing. If we didn't have someone internal that understood these principles it would have been difficult to get started and do the work in-house. Having a preservation group with technical background in area of corrosion is key. A lot of states have them, but without them it would be difficult

Steven – We don't have dedicated person in headquarters.

Randy – We don't either. We have some folks in our labs that do some of the work, but they are not part of the bridge program.

Bruce- We do this because we have coastlines. Our problems have forced us to deal with it by having corrosion specialists. For our big coastal structures, we had one so bad that we replaced it. But the public didn't want these coastal bridges to be lost. So, the preservation unit was started to preserve them.

Ray – The response to cash flow problems has made them supportive for this kind of preservation.

Luong – We have a preservation unit, but no corrosion specialist, so we outsource it.

Bruce – Our preservation unit has historic, movable, weld, and fatigue specialists. That's our unique unit that requires special training and certification.

Mike – Are there any roadblocks you see in Oregon for implementation?

Bruce – The bridge program has authority delegated to a section, so at that level we have budgets, but once we have the overall budget we have a lot of autonomy in working together and moving forward. If we had to go to the chief engineer for every new innovative thing we tried, that would be an impediment. But we don't have that.

Ray – We have someone constantly looking through the database to make sure things are getting done.

Andrew – In a broader sense, we have continuity between design and construction.

Mike – You need design, construction and operational people all involved.

Bruce – We have made serious attempts at implementing BIM. We get as-built drawings but what we don't have is a full live database for a specific bridge. We need the ability to go to a bridge and see specific mix design, joint material and model number, joint gland type. All information is available in hand written documents; but needs to be in electronic database so we can manage the structure better.

Mike – That's the idea of a birth certificate, but right now it's not in a database.

Ray – What you are talking about is a BIM.

Bruce – It could fit in a BIM.

Pam – SHRP 3

Paul – a few retaining walls – plan and elevation available but no more information.

Raj- we already have initiative on that

Bruce- even if you have infrastructure of BIM – we are not set up organizationally in Oregon to take advantage of that.

Joan – What document is used for the birth certificate?

Mike – Excel.

Joan – BIM level 2 or 3 can document this.

Mike – What we have so far is the idea of what information to document.

Andrew – ODOT has a research project with PSU to look at bridge deck deterioration metrics. Might be interesting to see what comes out of it. Due in next few months.

Ray/Andrew – It's been underway for 7-8 years.

Wrap Up & Adjourn

- **Additional Topics to Consider for Future Peer Exchanges**

Mike- We will consider issues with steel bridges and coatings, particularly in the eastern states

Bruce – The workshops will be different in each region. Oregon focused on specific areas

Paul – An MSE wall discussion would be appropriate. The abutment of choice these days often involves MSE walls. Proprietary walls submit service life calculations for straps.

Pam – Consider the work that Silas Nichols is doing with the Geotech tool.

Luong – ABC components and how it can be related to durability (joints, precast, UHPC, etc.)

Pam - Include the proposed Service Life Design Guide Specification as a topic.

Melissa – How service life design contributes to sustainability and the green roads initiative.

Neil – Need more definition on specifications for design build designing service life, and how to specify handback requirements in an objective way.

Appendix A – Agenda

SHRP2 R19A Service Life Design for Bridges
Oregon Peer Exchange, July 24, 2018

DoubleTree by Hilton - Portland
1000 NE Multnomah Street, Portland OR 97232

Time	Topic	Speakers
8:30 – 8:50 am	**Welcome and SHRP2 Introduction** • FHWA, AASHTO, & State Introduction (20 min)	Raj Ailaney, FHWA Pam Hutton, AASHTO Bruce Johnson, ODOT
8:50-10:15	• Service Life Design Concepts • Introduction to Service Life Design (SLD) (30 min) • Implementing Service Life Design for Concrete Structures (30 min) • Group Discussion Topic – What does 100-yr SLD mean? (20 min)	Mike Bartholomew, CH2M Neil Cumming, COWI All participants
10:15-10:30 am	**Break**	
10:30-12:00 am	**R19A Implementation Updates** • Goals of Oregon's R19A Participation (10 min) • Design of Ochoco Creek Bridge (25 min) • Bridge Deck Deterioration & Rehabilitation (30 min) • Group Discussion Topic – Challenges of Durability Testing (25 min)	Bruce Johnson, ODOT Paul Strauser, ODOT Andrew Blower, ODOT All participants
12:00-1:00 pm	**Lunch**	
1:00-2:20pm	**R19A Implementation Updates (continued)** • RFP for Service Life Design for Design-Build (D/B) Projects (20 min) • Group Discussion Topic – Challenges of D/B projects (20 min) • R19A Participation from Other Agencies (20 min) • NCHRP 12-108 Guide Specification for Service Life Design (20 min)	Craig Shike, ODOT All participants Mike Bartholomew, CH2M Bruce Johnson, ODOT
2:20-2:40 pm	**Break**	
2:40-4:30 pm	**Group Discussion Topics** (To be updated based on survey responses) • Design Issues – How is concrete cracking taken into account? • Construction – How can we verify the durability properties specified in design are achieved during construction? • In-Service – How can a regular monitoring plan be implemented to verify that performance matches design intent? • What Organizational Structures Are Required to Successfully Achieve Longer Lasting Bridges?	Bruce Johnson, ODOT - Facilitator All participants
4:30-5:00 pm	**Wrap Up & Adjourn** • Additional Topics to Consider for Future Peer Exchanges • Fill Out Evaluation Forms	Mike Bartholomew, CH2M

Appendix B – List of Attendees

SHRP2 R19A Service Life Design for Bridges
Oregon Peer Exchange, July 24, 2018
SIGN IN SHEET

Initial	Name	Agency
	Andrew Blower	OR
	Bruce Johnson	OR
	Craig Shike	OR
	Fatemeh Alapour	COWI
	Joan Zhong-Brisbois	WSP USA
	Luong Tran	WA
	Melissa Moncada	Jacobs
	Mike Bartholomew	Jacobs
	Neil Cumming	COWI
	Nicholas Rodda	WA
	Pam Hutton	AASHTO
	Paul Strauser	OR
	Raj Ailaney	FHWA
	Randy Ringstmeyer	WY
	Ray Bottenberg	OR
	Steven Kerr	SD
	Eric Run	

Appendix C – Summary of Evaluations

What were the most important ideas you learned from the workshop?

- Chloride testing and profiling techniques
- Transfer function for concrete near surface
- Chloride migration and testing
- Value of Chloride testing on deck rehab/programing
- Learning about the NT Build 492 test and how that can determine a given concrete mix's chloride migration coefficient and how that is used with chloride profile to determine resistance
- Material durability is part of resistance; grapline solutions for SLD; durability testing
- Learning what other lead states are studying
- SLD Approaches – problematic

Are there questions or issues you wished the workshop had addressed that it didn't?

- Pre-cast/ ABC components

Would you like to learn more about the SHRP2 *Service Life Design for Bridges* (R19A) product?

- 5 Yesses
- How chloride level is calculated.

Please provide us with additional comments, feedback, or ideas related to this event or future SHRP2 events:

- Very good peer exchange
- More examples would be helpful
- Better room layout – coffee would be welcome
- Additional participation of non- IAP states would be valuable.

Rating	Subject knowledge level prior to workshop	Subject knowledge level after workshop	Knowledge of SHRP2 prior	Knowledge of SHRP2 after	Overal Content Effective	Presentation Effectiveness	Provided a better understanding of implementing	I understand how Service Life Design can benefit my agency	Encouraged Active Participation	Was worthwhile	Expectations Met	Presented clear information
1	1	0	4	0	0	0	0	0	0	0	0	0
2	2	0	1	0	0	0	0	0	0	0	0	0
3	1	0	2	0	0	0	0	0	0	0	0	0
4	2	0	0	0	0	0	0	0	0	0	0	0
5	1	1	0	1	0	0	0	0	0	0	0	0
6	0	1	0	2	1	0	1	0	1	0	0	0
7	1	3	1	1	1	2	0	1	1	2	2	2
8	3	4	1	2	5	6	3	5	3	3	3	1
9	1	**3**	1	4	3	4	4	3	4	4	6	7
10	0	0	2	2	1	0	3	3	3	3	1	2
strongly disagree (1-2)	3	0	5	0	0	0	0	0	0	0	0	0
moderately disagree (3-5)	4	1	2	1	0	0	0	0	0	0	0	0
moderately agree (6-8)	4	8	2	5	7	8	4	6	5	5	5	3
strongly agree (9-10)	1	3	3	6	4	4	7	6	7	7	7	9
sum	12	12	12	12	11	12	11	12	12	12	12	12
% strongly disagree	25%	0%	42%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% moderately disagree	33%	8%	17%	8%	0%	0%	0%	0%	0%	0%	0%	0%
% moderately agree	33%	67%	17%	42%	64%	67%	36%	50%	42%	42%	42%	25%
% strongly agree	8%	25%	25%	50%	36%	33%	64%	50%	58%	58%	58%	75%