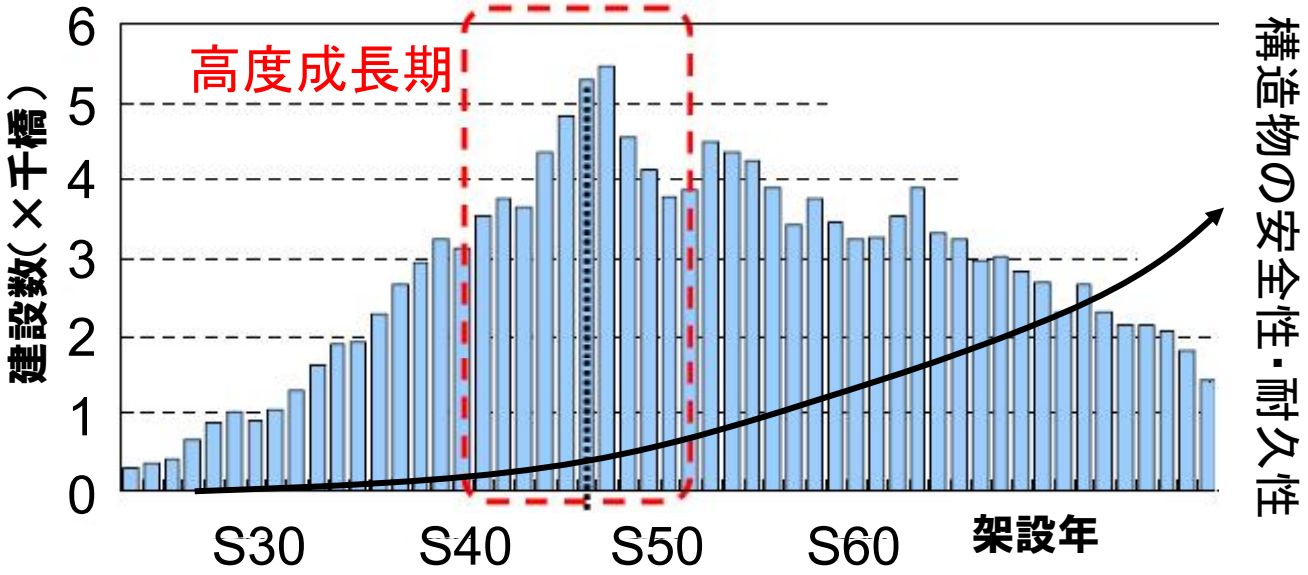
委員からの話題提供
（秋山委員提供資料）

－資料2－

既存インフラ構造の高齢化・老朽化

●橋梁架設数の推移



- コンクリートクライシス（1980年代），宮城県沖地震（1978年）や兵庫県南部地震（1995年）の経験とその後の研究の進展により，構造物の安全性・耐久性は確実に向上している．

- 既存インフラ構造の問題は，現在に比べて，建設当時の初期状態においても安全性・耐久性に乏しい構造物が高齢化していることにある．各年代の構造物が持つ固有の問題を正しく認識する必要がある．

メインテナンスの実践で何が問題か？

本格的なメインテナンス時代の前に解決すべき問題

問題1：腐食ひび割れを有する構造物はどの程度初期状態より構造安全性が低下しているのか？

問題2：あと何年間，安全に使用できるのか？（余寿命は何年か？）

問題3：どのような点検・検査結果が得られた場合が倒壊の危険信号か？

問題4：適切な補修・補強の実施時期は？

医療の現場：誕生 → 成長・青年期 → 老化の進行 → 発病・悪化 → 死亡

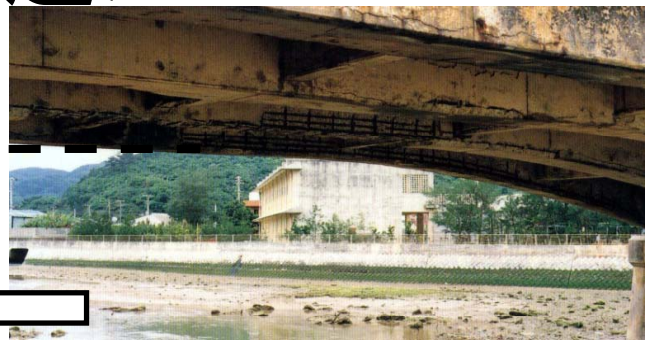
膨大なサンプルの蓄積
⇒点検・検査に基づき，患者の状況に応じた適切な診断



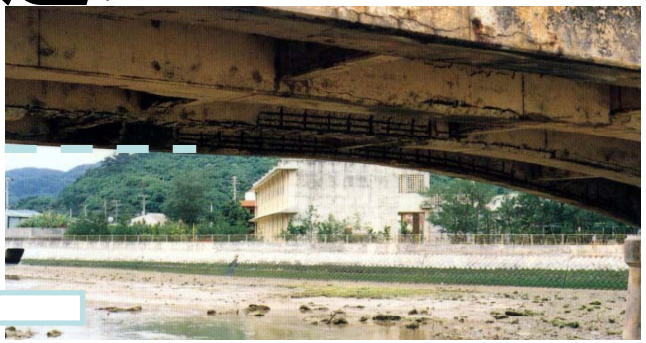
インフラ構造：竣工・健全 → 潜伏期 → 劣化の顕在期 → 損傷・倒壊 → 架け替え

竣工から倒壊までの劣化の変状をモニターした事例が皆無
⇒点検・検査に基づきインフラ構造の余寿命評価が現時点で困難

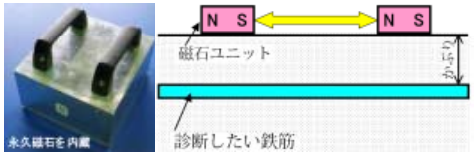
メインテナンスの実践で何が問題か？

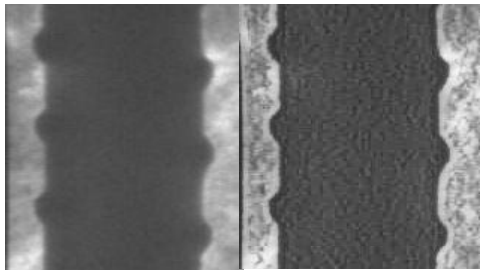


メインテナンスの実践で何が問題か？



研究の方向性　様々な要素技術のインテグレーションによるインフラ構造の長寿命化技術の高度化





センシング技術・SHM

ハザード評価

腐食過程の可視化

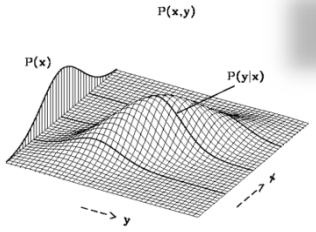
持続可能社会を支える
インフラ構造

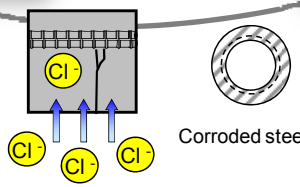
Life-Cycle Cost

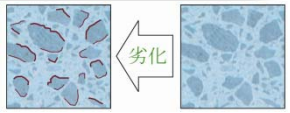
Optimization

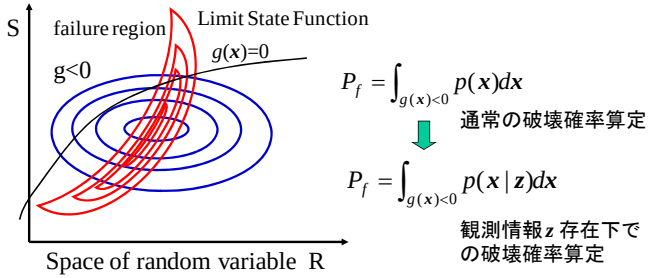
Updating・更新理論

信頼性解析









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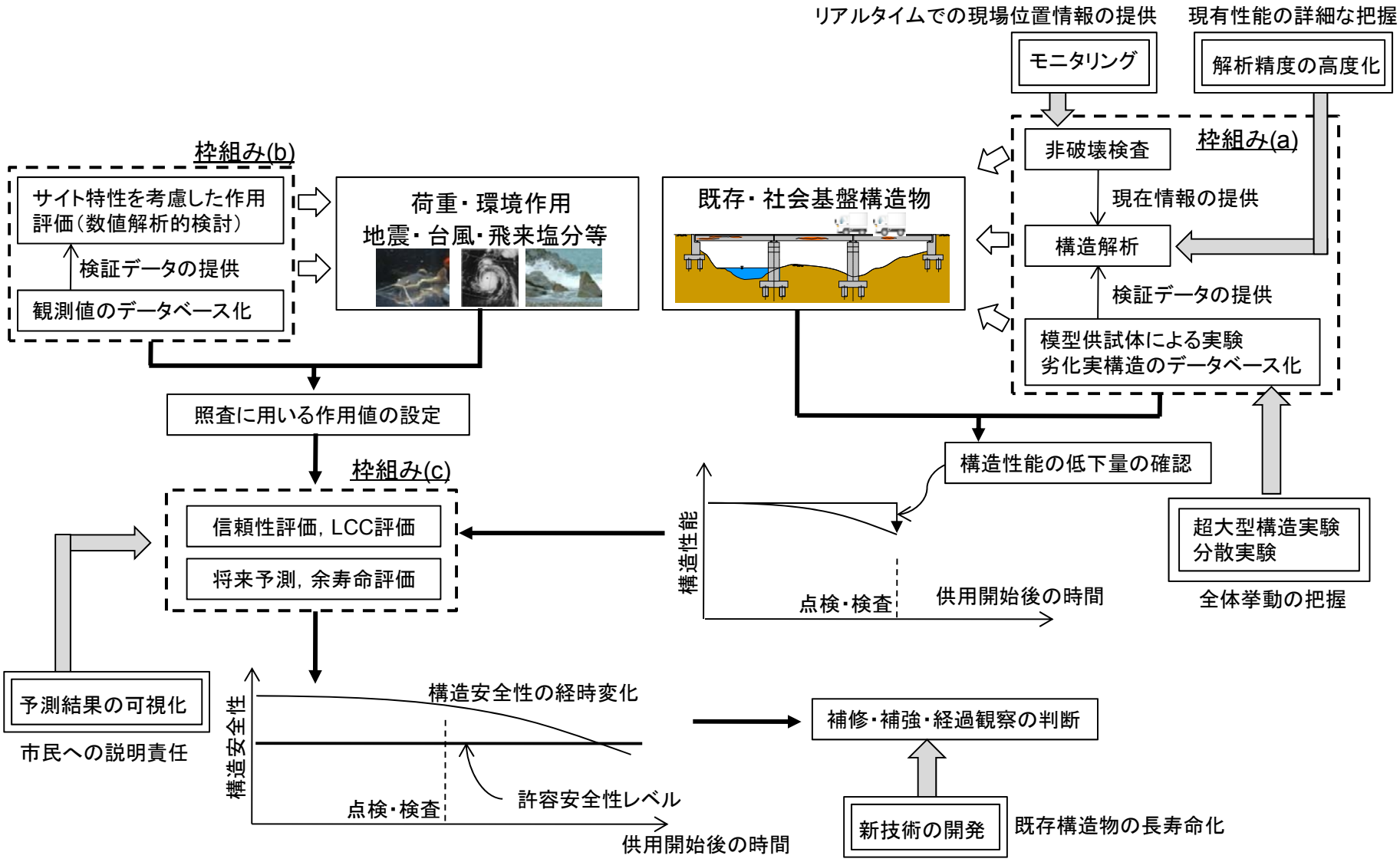


予防保全を行うことが維持管理の全て？

維持管理とは，構造物の性能の現状を定期的に確認するとともにその将来も予測し，予定供用期間中に要求性能を満足しなくなる状況が考えられる場合には，性能の回復あるいは保持のための対策を講じる一連の行為をいう（コンクリート標準示方書・維持管理編2007）．

要求性能を満足しなくなる状況を生み出す要因

荷重・作用	交通荷重	塩害	地震	風荷重	クリープ
	津波	中性化	疲労	温度	乾燥収縮
構造耐力	高齢化	不適切な施工			
	設計当時の技術不足　（耐久性・耐震性などへの理解不足）				
その他	予算不足				

既存インフラ構造物に対する要求性能は何か？
最も重要な構造物の安全性にとっての脅威は何か？

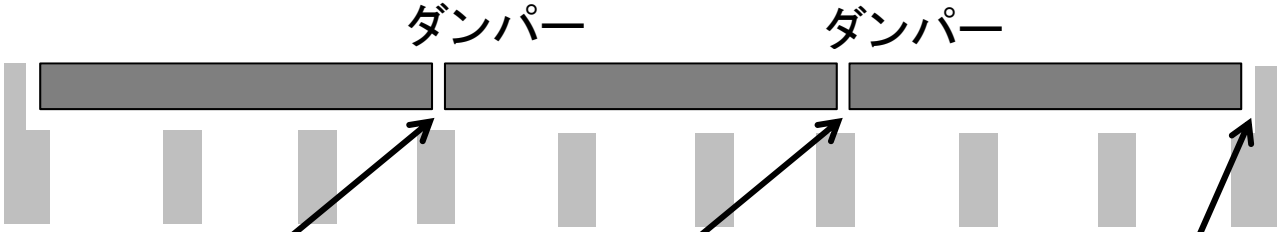
材料劣化への対処か？　耐震補強か？

予算Bが与えられたとき，要求性能を満足しなくなる状況を避けるには何をすべきか？

Seismic Risk $\leqq$ Risk Associated with Material Deterioration

検討項目
⇒橋梁の重要度・建設年代・破壊の脆弱性・地震ハザード・劣化の進行度・腐食環境

東北地方太平洋沖地震後に調査した道路橋



既存インフラ構造にとっての脅威は高齢化？地震？

Damage of Highway Bridges Due to The 2011 off the Pacific Coast of Tohoku Earthquake (土木研究所資料)

撮影（京都大学・高橋良和先生）

東北地方太平洋沖地震で被災したRC橋梁

⇨ 地震は，インフラ構造物の安全性を最も脅かす脅威
耐震補強は維持管理における重要な検討項目の一つ

耐震補強ですら中々進まない現実・・・

東北地方太平洋沖地震で被災したRC橋梁

- 兵庫県南部地震から17年が経過しても，東北地方太平洋沖地震程度の地震力で損傷する構造物が未だに多数ある．地震工学分野の研究の進展，あるいは耐震技術の進歩が予算制約のために社会に還元されない．
- 1995年以降，Mw=6.5以上の地震が頻発しているのに耐震性能が低いまま放置されている構造物が多数ある．結局，維持管理技術が向上しても，予算的な問題から放置される構造物が多数出てしまうのではないか？

膨大な数の既存構造物

予算的制約と時間的制約の中の葛藤…

全ての既存構造物を現行基準で設計される構造物と同じ性能を有するように補強していくことを要求するのは，予算的制約から極めて困難．

構造物管理者は，配分された予算で最大の効果を上げるため努力されている．これ以上に維持管理のスピードを上げるためにはプラスαの何かが必要．

安全性が十分でない構造物の補強を進める上でのチャレンジは，自然災害や構造物の性能レベルについての知識・経験が少ない市民に実際の状況を直接的に提示することか？

何か被害が出るくらいなら，負担してでも既存インフラ構造の維持管理を進めることを望んでいないか？

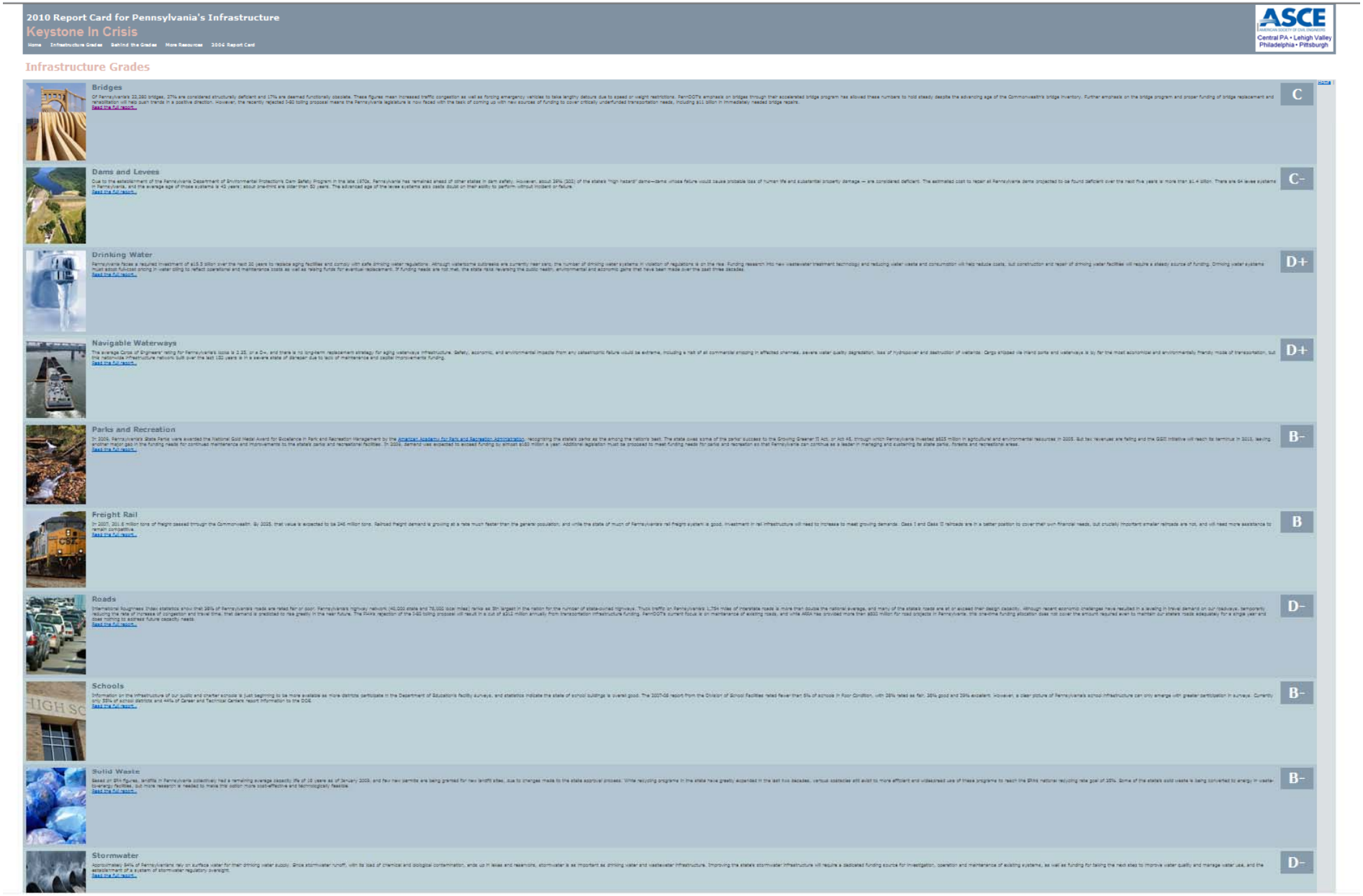
⇨ 情報発信は十分か？

ASCEの例

非常に多くの種類のインフラ構造物の現状（劣化状態）と対策費の概算が示されている.

全州に対する総括と各州のデータがホームページで公開されている

ASCEの例（PAの例）



2010 Report Card for Pennsylvania's Infrastructure

Keystone In Crisis

Home　Infrastructure Grades　Behind the Grades　More Resources　2006 Report Card

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS
Central PA • Lehigh Valley
Philadelphia • Pittsburgh

Infrastructure Grades

Bridges — C

Of Pennsylvania's 22,390 bridges, 37% are considered structurally deficient and 17% are deemed functionally obsolete. These figures mean increased traffic congestion as well as forcing emergency vehicles to take lengthy detours due to speed or weight restrictions. PennDOT's emphasis on bridges through their accelerated bridge program has allowed these numbers to hold steady despite the advancing age of the Commonwealth's bridge inventory. Further emphasis on the bridge program and proper funding of bridge replacement and rehabilitation will help push trends in a positive direction. However, the recently rejected I-80 tolling proposal means the Pennsylvania legislature is now faced with the task of coming up with new sources of funding to cover critically underfunded transportation needs, including $11 billion in immediately needed bridge repairs.

Read the full report.

Dams and Levees — C-

Due to the establishment of the Pennsylvania Department of Environmental Protection's Dam Safety Program in the late 1970s, Pennsylvania has remained ahead of other states in dam safety. However, about 24% (302) of the state's "high hazard" dams—dams whose failure would cause probable loss of human life and substantial property damage — are considered deficient. The estimated cost to repair all Pennsylvania dams projected to be found deficient over the next five years is more than $1.4 billion. There are 64 levee systems in Pennsylvania, and the average age of those systems is 43 years; about one-third are older than 50 years. The advanced age of the levee systems also casts doubt on their ability to perform without incident or failure.

Read the full report.

Drinking Water — D+

Pennsylvania faces a required investment of $15.3 billion over the next 20 years to replace aging facilities and comply with safe drinking water regulations. Although waterborne outbreaks are currently near zero, the number of drinking water systems in violation of regulations is on the rise. Funding research into new wastewater treatment technology and reducing water waste and consumption will help reduce costs, but construction and repair of drinking water facilities will require a steady source of funding. Drinking water systems must adopt full-cost pricing in water billing to reflect operational and maintenance costs as well as raising funds for eventual replacement. If funding needs are not met, the state risks reversing the public health, environmental and economic gains that have been made over the past three decades.

Read the full report.

Navigable Waterways — D+

The average Corps of Engineers' rating for Pennsylvania's locks is 2.35, or a D+, and there is no long-term replacement strategy for aging waterways infrastructure. Safety, economic, and environmental impacts from any catastrophic failure would be extreme, including a halt of all commercial shipping in affected channels, severe water quality degradation, loss of hydropower and destruction of wetlands. Cargo shipped via inland ports and waterways is by far the most economical and environmentally friendly mode of transportation, but the nationwide infrastructure network built over the last 150 years is in a severe state of disrepair due to lack of maintenance and capital improvements funding.

Read the full report.

Parks and Recreation — B-

In 2009, Pennsylvania's State Parks were awarded the National Gold Medal Award for Excellence in Park and Recreation Management by the American Academy for Park and Recreation Administration, recognizing the state's parks as the among the nation's best. The state owes some of the parks' success to the Growing Greener II Act, or Act 45, through which Pennsylvania invested $625 million in agricultural and environmental resources in 2005. But tax revenues are falling and the C2D2 initiative will reach its terminus in 2013, leaving another major gap in the funding needs for continued maintenance and improvements to the state's parks and recreational facilities. In 2009, demand was expected to exceed funding by almost $163 million a year. Additional legislation must be proposed to meet funding needs for parks and recreation so that Pennsylvania can continue as a leader in managing and sustaining its state parks, forests and recreational areas.

Read the full report.

Freight Rail — B

In 2007, 201.5 million tons of freight passed through the Commonwealth. By 2035, that value is expected to be 245 million tons. Railroad freight demand is growing at a rate much faster than the general population, and while the state of much of Pennsylvania's rail freight system is good, investment in rail infrastructure will need to increase to meet growing demands. Class I and Class II railroads are in a better position to cover their own financial needs, but crucially important smaller railroads are not, and will need more assistance to remain competitive.

Read the full report.

Roads — D-

International Roughness Index statistics show that 28% of Pennsylvania's roads are rated fair or poor. Pennsylvania's highway network (40,000 state and 76,000 local miles) ranks as 5th largest in the nation for the number of state-owned highways. Truck traffic on Pennsylvania's 1,754 miles of Interstate roads is more than double the national average, and many of the state's roads are at or exceed their design capacity. Although recent economic challenges have resulted in a leveling in travel demand on our roadways, temporarily reducing the rate of increase of congestion and travel time, that demand is predicted to rise greatly in the near future. The PHRA rejection of the I-80 tolling proposal will result in a cut of $211 million annually from transportation infrastructure funding. PennDOT's current focus is on maintenance of existing roads, and while ARRA has provided more than $600 million for road projects in Pennsylvania, this one-time funding allocation does not cover the amount required even to maintain our state's roads adequately for a single year and does nothing to address future capacity needs.

Read the full report.

Schools — B-

Information on the infrastructure of our public and charter schools is just beginning to be more available as more districts participate in the Department of Education's facility surveys, and statistics indicate the state of school buildings is overall good. The 2007-08 report from the Division of School Facilities rated fewer than 5% of schools in Poor Condition, with 29% rated as fair, 36% good and 29% excellent. However, a clear picture of Pennsylvania's school infrastructure can only emerge with greater participation in surveys. Currently only 35% of school districts and 44% of Career and Technical Centers report information to the DOE.

Read the full report.

Solid Waste — B-

Based on EPA figures, landfills in Pennsylvania collectively had a remaining average capacity life of 16 years as of January 2009, and few new permits are being granted for new landfill sites, due to changes made to the state approval process. While recycling programs in the state have greatly expanded in the last two decades, various obstacles still exist to more efficient and widespread use of these programs to reach the EPA's national recycling rate goal of 35%. Some of the state's solid waste is being converted to energy in waste-to-energy facilities, but more research is needed to make this option more cost-effective and technologically feasible.

Read the full report.

Stormwater — D-

Approximately 84% of Pennsylvanians rely on surface water for their drinking water supply. Since stormwater runoff, with its load of chemical and biological contamination, ends up in lakes and reservoirs, stormwater is as important as drinking water and wastewater infrastructure. Improving the state's stormwater infrastructure will require a dedicated funding source for investigation, operation and maintenance of existing systems, as well as funding for taking the next steps to improve water quality and manage water use, and the establishment of a system of stormwater regulatory oversight.

Read the full report.

まとめ

1. 材料劣化と構造性能の低下の関係の整理は，研究段階である．予防保全的な対応が必要（通常は，この対応がLCC最小）．

2. 維持管理の高度化には，点検やセンシング・構造解析・LCC解析・補修や補強技術等，分野横断的な連携が必須である．

3. 対象構造物に求める要求性能を明確にする．その性能を満足しなくなる状況を生み出す荷重・作用を特定し，対策（補修・補強）を施す．

4. これだけ頻繁に地震が発生している状況でも，予算的制約から耐震補強が進まない現実がある．既存のインフラ構造物の維持管理に必要となる予算への理解を得るため，インフラ構造物の重要性，その性能の現状などを社会に発信するさらなる努力が必要では？