Organization and Outcomes from a United States Consortium of Accelerated Pavement Testers

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ABSTRACT

Accelerated pavement testing (APT) programs in the United States have a rich history ranging from evaluation of locally available pavement materials to nationally significant test tracks such as the milestone AASHO Road Test or the recent MnROAD, WesTrack and the NCAT test tracks. A significant portion of APT programs in the United States are funded by State DOTs with the rest being Federal (FHWA, Army Corps of Engineers), academic and private facilities. Varieties of APT facilities seek collaboration and partnerships to make greater impacts. The National Cooperative Highway Research Program (NCHRP) has delivered three syntheses to establish a state of the practice and to further assist APT facilities continually improve their programs. NCHRP Synthesis 235 (Metcalf, 1996) provides an extremely comprehensive report on the capabilities, limitations, objectives, instrumentation and effectiveness of worldwide programs over the world. A more focused effort for data guidelines is given in NCHRP Report 512 (Saeed and Hall, 2003) recommending protocols for collecting, storing and distributing data from APT facilities. These provide for more efficient analyses and enhanced cross comparisons between facilities. NCHRP Synthesis 325 (Hugo and Epps-Martin, 2004) builds upon Synthesis 235 and explores in greater depth and breadth the application of APT, significant findings and economic analyses of APT programs since 1996.

The Consortium of Accelerated Pavement Testers (CAPT) is a group of APT facility owners and operators in the United States that seeks to make impacts like the NCHRP efforts. However, unlike periodic studies and publications, the CAPT attempts to provide more continuous attention with a forum-like structure to discuss and improve relevant APT issues. The CAPT is operated under the Transportation Pooled Fund program (www.pooledfund.org) sponsored by FHWA, TRB and AASHTO that enables technology transfer activities to be jointly funded by several federal, state, regional, and local transportation agencies, academic institutions, foundations, or private firms as a pooled fund study. The Mission of the CAPT is to share and develop best practices and collaborate in experimental design, data acquisition, data sharing, and validation of findings. The Vision of the CAPT is that owners and operators will improve and economize their operations and accelerate acceptance of pavement performance findings.

HISTORICAL PERSPECTIVE

FHWA organized a series of two meetings in the summers of 2004 and 2005 at two locations to gather interested facilities and participants in forming a consortium under the Transportation Pooled Fund system. The first meeting between eight State, FHWA and TRB members discussed the possibility of collaborating on future accelerated pavement testing. The second meeting expanded upon the number of participants and discussed making impacts beyond networking and measuring success over a finite amount of years.

The third meeting organized by FHWA and hosted by the University of New Hampshire Recycled Materials Resource Center (RMRC) took place in the fall of 2005. The CAPT, not yet an official pooled fund project, discussed fundamentals of pavement instrumentation in the context of the meeting's theme of recycled construction materials. The meeting enabled US APT facilities to become more familiar with the activities of the RMRC while the RMRC knowledge of APT resources expanded and gathered input regarding what recycled materials and construction issues could and could not be studied adequately using APT. The recently re-organized RMRC now has a Pooled Fund solicitation to gather participants in pooled funds projects that increase the wise use of recycle materials in highway construction and maintenance (FHWA, 2008a).

A significant amount of strategic planning and brainstorming took place in the fourth meeting at the University of California-Davis as the CAPT prepared for formal organization under the Transportation Pooled Fund System. The group worked together in breakout sessions to develop a strategic plan with Emphasis Areas that reflected the 10 most relevant APT issues. These Emphasis Areas are discussed further in this paper with outcomes from several pursued.

The CAPT was established as Pooled Fund project in 2007 and held two meetings at the NCAT Test Track facilities and Florida DOT Heavy Vehicle Simulator facility when funding became self sufficient under the program. The participants are shown in Figure 1. The focus of the meetings was to provide forums for APT construction practices, instrumentation, data acquisition networks. Also, the CAPT discussed the nationally significant, emerging need to develop a plan for highway infrastructure agencies to understand the impact of new generation wide base single truck tires replacing a more significant portion of the standard dual tire configuration. A pooled fund solicitation is now available from the Illinois Department of Transportation (FHWA, 2008b) titled “Impact of Wide-Base Tires on Pavement Damage: A National Study.” The Western Research Institute’s Asphalt Research Consortium also held a workshop to gather input form pavement mechanics experts to identify what scientific knowledge and tools are necessary to adequately undertake the research (University of Nevada, 2008).

CAPT EMPHASIS AREAS

Participants of the CAPT have very diverse duties and range from facility managers, engineers, graduate students and technicians. A plan was needed so the CAPT’s efforts would be both balanced and focused. Otherwise, the meetings and discussions could serve some of the participants better than others.

The CAPT has set goals and tasks in ten key Emphasis Areas in Table 1. For brevity, the individual tasks are omitted. Working on all ten areas requires resources outside those available to the CAPT. Once these Emphasis Areas were developed, priority was given to a attainable amount; Area 3, Area 4 and, to a lesser degree, Area 1. Nonetheless, other Emphasis Areas do not necessarily have to be addressed by CAPT members, but by other activities such as TRB workshops. For instance, Area 8 benefits from the 2008 TRB workshop Validation of Advanced Flexible Pavement Modeling with Accelerated Pavement Testing Data. Below are outcomes from the CAPT Emphasis Areas pursued.

Facility and Equipment Advances - Emphasis Area 1

There is a link between Emphasis Area 1 and Emphasis Area 4. The CAPT desires to stay up to date on the most recent advances in instrumentation to continuously improve current methodologies. To do so, a Rodeo or hands-on demonstration workshop is envisioned to address the gaps and needs. The CAPT has developed a framework and description of what activities should be pursued. The objective of the Pavement Instrumentation Rodeo is to establish state-of-the-practice and state-of-the-art instrumentation technical dialog between different instrumentation users and between instrumentation vendors and users in the areas of:

- New technologies and cutting edge areas that may be known and not tried
- Demonstrating that unfamiliar systems or historically difficult systems can work and how they work
- Understanding instrumentation operation in both the laboratory and the field
- Establishing feasible ranges for instrumentation users’ needs
- Installation practices and retrofit in-place practices
- Sensor protection
- Signal interpretation

The intent of the Rodeo is not to rate or rank specific technologies against one another, but to allow instrumentation users to improve what they do. Due to travel and construction schedules formalized sensor rodeos may not be practical, but efforts by each facility can be made. MnROAD is developing one interstate test cell to review a number of strain and moisture gauges for the CAPT and its own use during its 2008 reconstruction.

Construction Site Practices and Procedures at APT Facilities – Emphasis Areas 3

APT construction practices and procedures were synthesized from CAPT meetings and follow-up surveys and correspondence. A separate paper submitted by Willis and Powell to the 3rd International Accelerated Pavement Testing Conference provides an expanded discussion of undesired pavement failures associated with improper APT construction, contracting and in-house methodologies, quality control and quality assurance (Willis and Powell, 2008). No two APT experiments are designed to obtain the exact same results using identical loading scenarios; therefore, it is impossible to create a “one-size fits all” construction scenario for all APT facilities. Based on the survey results and previous literature review, the following conclusions can be made:

- Using experienced contractors under a comprehensive construction contract will improve quality of the experiment and free facility staff to perform other duties.
- Base and subgrade densities are the most difficult material properties to achieve due to the unique construction requirements of test sections/pits.
- Binder content, air voids, and VMA are the three most tested HMA construction properties at APT facilities in the United States.
- Nuclear gauges are the most prolific form of density testing used at APT facilities in the United States.
- 28-day compressive strength is the only consistent property tested among APT facilities using PCC.

The following recommendations can be given for construction practices based upon experiences seen at APTs in the United States:

- Communicate specifically and openly with contractors to ensure the project specifications are clear pre-construction.
- Be flexible with compaction efforts. Try something new if traditional efforts are not working.
- Ensure uniform materials are placed before trafficking commences to inhibit early failure through proper monitoring and testing procedures.
- Continue research into construction practices of APT facilities. The more these facilities learn from each other's successes and failures, the better the results will be for the pavement community.
- Surveys did not provide adequate information to convey information about proper PCC construction. More research should be conducted on successes in PCC construction at APT facilities.

Gaps and Needs in APT Instrumentation - Emphasis Area 4

Instrumentation is a critical component of an APT program and cross-cut areas of construction and experimental design. The following are reasons and motivation identified by the CAPT as to why instrumentation is employed:

- Validation and development of pavement response and distress models
- Sometimes APT cannot bring pavements to failure thus rely on measured primary responses and models that can indirectly provide expected pavement failure. In other words; to link APT performance (distress) and primary response (stress-strain)
- Qualitatively and quantitatively check construction
- Monitor hardening and maturity of PCC
- Assist in operating APT facilities such as determining axle load magnitude or when to change or stop loading
- Distress mechanism verification such as how cracking is induced or rutting develops

The CAPT has further determined when developing instrumentation plan for an experiment it is critical to ask, "Can it be measured?" and, "Is it right or wrong to measure it? Is what you are measuring realistic?" The following questions and gaps are of interest for synthesis and will be different depending on the type of APT program whether a test track, indoor APT facility or outdoor APT facility:

- What is the most prized or default method of instrumentation for a certain response?
- What are the pros and cons with specific instrumentation?
- Specifically how would the APT community like the see new technologies create better instrumentation? Smaller, cheaper, easier to install, less influence of surrounding, durable, convenient, user friendly etc.
- Sharing the capabilities of each facility instruments' resolution, precision and range.
- Identify and summarize any repeatability or comparison studies which may have been completed.
- Establish or state how researchers understand what the instruments readings provide – i.e. interpretation of strain gauge responses.

- What are the current experiences and best practices for handling and installation such as fragility, robustness, survivability, lifespan, and durability; i.e. lead wire protection from the elements.
- Identification and summarize any special practices for verifying instrumentation operability as-delivered and on-site calibration methods
- Documented observations of instrumentation electrical signal interference and noise along with mitigation techniques
- What are some instrumentation methods or instruments facilities may be aware of but not tried?
- Peer review of facility-specific or customized instrumentation data analysis.

The CAPT further identified that there were basically three types of pertinent instrumentation; Environmental, Primary Response and Secondary Distresses. Table 2 presents ranked interest of different pavement conditions and response each of the categories. Of note is the largest number of votes and interest in strain. Thus, a cross cutting analysis of strain practices has been identified as a high priority area for the CAPT, which will be relevant to overall pavement engineering community as well.

The interest of the CAPT reflects the desire to see the state-of-the-practice for instrumentation advance and improve research. These desires include developing instrumentation which is currently not available, improving installation, increasing survivability and life, more rugged and durable devices, decrease disturbance and influence of surrounding material, facilitating calibration, improve or develop new and better ways to collect, manage, analyze and interpret the data, etc. A very broad range of instrumentation is used among the CAPT. There are similarities in experience and methodology. Some facilities have developed unique equipment and methodologies and usually in response to learning from past events and available resources.

The unique instrumentation experience of the CAPT members was synthesized from CAPT meetings and follow-up surveys and correspondence. A separate paper submitted by Willis to the 3rd International Accelerated Pavement Testing Conference provides an expanded discussion (Willis, 2008). Highlights from the synthesis are provided. It is imperative that facilities choose instrumentation properly when beginning instrumented APT or in-service roadway research. One of the most beneficial ways to determine appropriate instrumentation practices is to look at the successes and challenges of other research experiments to benefit from lessons learned. The following conclusions can be made:

- Horizontal strain gauges can be used to quantify pavement responses which predict pavement fatigue life. Dynatest and CTL produce the most commonly used devices for capturing this pavement response.
- Vertical strain is very rarely measured; however, LVDTs can be used to measure pavement deflection and return similar results.
- APT has seen an increased use of pressure cells. Most facilities are commonly incorporating these gauges in pavement research.
- Thermocouples are more commonly used to measure temperature at APT facilities; however, while not as commonly used, thermistors have returned reliable data to researchers.
- Installation of gauges is one of the most important factors in determining if a gauge is going to behave correctly.

The following recommendations can be made to further advance the field of research involving instrumented pavements.

- Sensors need to be compared to determine the working ranges and qualities of the various gauges. CAPT plans to conduct a sensor rodeo where gauge comparisons can be investigated.
- Gauges should be calibrated and checked before being installed in pavements for research. This will ensure gauges are behaving properly.
- Duplication of gauges allows researchers to check the quality of the data. In HMA pavements, at least two strain gauges should be placed in the transverse and longitudinal direction to allow for functionality checks. If wheel wander is present and uncontrolled as in a test track, additional gauges should be considered to accurately quantify this phenomenon.
- Further research needs to be conducted on developing accurate and reliable devices for measuring the moisture contents of soils. Specifically, alternatives to Time Domain Reflectometry (TDR) are strongly desired.
- Further research also should be encouraged into the data acquisition systems, signal processing programs, and in-situ accuracy verification programs used at APT facilities. Currently, a study is

being conducted at the NCAT Pavement Test Track to determine the precision of their strain gauges along with other facilities. MnROAD is developing an improved strain gauge processing and peak-picking methodology. Other studies should be conducted to determine appropriate working ranges for gauges in question.

Relation between APT and Theoretical Models for Pavement Response and Distress - Emphasis Area 8

The goals of the 2008 TRB workshop were to identify important aspects of modeling that are relevant to APT community, document current experience in model validation with APT experiments, present realistic characteristics of pavement materials that must be captured by material models in the laboratory, and identify areas where models can be improved based on APT data.

Aspects of modeling that are relevant to APT community

- The ability to capture construction effects in pavement models such as quality of tack coats is desired, if not necessary, because construction has an amplified influence on APT experiments.
- APT strategically utilizes instrumentation to quantify the degradation of the pavements structure my measuring the changes in primary responses (deflection, stress and strain). These tend to be more useful than measuring secondary distress (cracking rutting) because primary responses provide the closes most direct link to pavement models. For example, utilization of multi-depth deflectometers is critical to the real-time or post-experimental analyses of the accelerated pavement test.
- At times, models may be used to determine if hypothetical changes in the pavement structure are occurring when instrumentation is inadequate to provide this information; de-bonding is an example.

Realistic characteristics of full-scale and APT pavement materials that must be captured by material models in the laboratory

- Models utilizing a translating load with viscoelastic constitutive equations instead of elasticity to describe the asphalt layer have been found consistently useful and necessary when the shape of the strain history is important. However, elastic models are generally satisfactory to explore peak measured strains, but cannot adequately provide the measured shape of the strain signal. Accurately capturing the strain history is important to understanding multiple axles and damage phenomena which may be rate-dependent and/or sensitive to coupled tensile-compressive phenomena.
- The degree to which viscoelasticity is necessary/useful for other full scale and APT analyses applications has not been demonstrated.
- Small scale laboratory wheel tracking tests can provide important model validation before proceeding to or in addition to full-scale and APT validation of models. Such tests have the ability to produced dilated shoulders at the edges of rut paths which can validate a material model’s multiaxial capabilities because of the nature of the induced stresses at the location.
- Fatigue is generally a distress of importance in pavements of greater age in their life cycles. However, the density of asphalt layers does change contemporary with the accumulation of fatigue damage. There is a need to make better connections to these coupled phenomena with respect to laboratory fatigue characterization methodologies.
- Mechanical damage from thermal expansion and contractions, not limited to classical extreme low temperature events, will more than likely come under greater scrutiny with advanced models which can track that damage. Small amounts of damage are generally expected and models should be checked for reasonableness such that they do not predict damage which is significantly larger than expected.

- The importance of healing phenomena associated with asphalt concrete pavements is becoming more significant. Further, transfer functions between laboratory distresses and field distress can be quite large. The role which healing may have in improving transfer functions is not known but may be a strong candidate to investigate. APT is well poised for this.

Appropriate APT Experiments to Support Advanced Models

- Pavement instrumentation tends to favor measuring vertical stresses and less so for horizontal. Lateral stresses are coming under more and more scrutiny especially as base and other unbound material properties are investigated.
- Far field stresses, including lateral stresses, are also coming under scrutiny as dynamic effects become more important such as seismic field characterization tools.
- The degree to which mixed extension and compression in the laboratory explain cracking in asphalt pavement could benefit from more attention because this phenomenon occurs in full scale and APT. Most laboratory characterization is single sided – flexure, compression only, tension only. Further, advanced models which account for damage eventually need to be extended to include growing damage which couples extension, compression and multiple axes. This is a major undertaking.
- APT experiments can generally be designed to produce a single distress. Such APT experiments can be valuable when determining whether pavement performance prediction with advanced models or based on advanced models should couple the different distress that can occur simultaneously. Or is a “Binary Model” sufficient? One interpretation of a “Binary Model” is that when appropriate conditions are reached the active distress of interests (and associated internal state variables, etc) are switched on/off.
- Related to the above, an APT experiment which can be specifically designed and executed for either classical bottom-up cracking or top-down cracking.
- Can an experiment and associated modeling be conducted to determine if engineers can design against delaminating at all? Is it something within APT facility operators’ control? Is it only associated with large APT loads or poor tack coats?

Current experience in model validation with APT experiments

- Instrumentation is absolutely key. Many times it provides the only measure of truth or approximations of truth
- Best practices should be followed to ensure that instrumentation is not compromised during construction and should be checked. For example, ensuring that materials that are not rate dependent indeed do not exhibit rate dependence.
- In a non-technical departure, more education and awareness is needed to communication to practitioners that finite element methodologies (FEM) and advanced models are not a direct replacement for the practice and transfer functions and the like. FEM and advanced models are intended to provide more insight to problems where conventional practice and empirical methodologies are insufficient.

Identify areas where models can be improved based on APT data

- Pavement layer delaminations and slippage cause concern and may significantly influence primary response and performance during APT experiments. The value and utility of a model can be increased by applying it to scenarios where de-lamination may be likely or suspected such as composite pavements. The model can provide insight as to whether unexpected or highly damaging stresses or redistribution of stresses is occurring.
- The value and utility of models can also be increased by allowing a practitioner to take a core from an existing pavement showing distresses, perform characterization of the material in that state and them – like a remaining life prediction. This scenario is contrasted with the conventional scenario with all new construction in APT experiments (and the field).

- More computationally efficient numerical methods in engineering mechanics is always welcomed along with increases in processor speed
- Models can provide links between laboratory tests where the method of loading and prescribed stress states cannot reproduce field stress states.
- Research has shown that some models have included an additional manner of validation using small scale wheel tracking tests. Like in the full scale case, a moving load induces continually changing multiaxial stress state. These validations can provide complement to the larger full scale validation tests.
- Test roads, test tracks and APT devices can and do encounter moisture effects in unbound layers. Concerns have been voiced that pore water is being either ignored or inadequately represented in current modeling efforts. There is a desire to see integration of different models such as coupling mechanical constitutive models with transient fluid flow models to address

SUMMARY OF OUTCOMES AND FUTURE DIRECTION

APT facilities communicate and collaborate to make greater impacts. State transportation agencies and their partners in the United States have organized the CAPT for this purpose. The CAPT seeks a more forum-like structure to provide continuous attention to the research needs and practices. The CAPT has organized under the Transportation Pooled Fund system and has worked with or helped triggered other Pooled Fund research activities that include beneficial use of recycled materials and construction and methodologies to determine how nationally significant changes in freight tire characteristics impact pavement performance.

The CAPT has developed ten key Emphasis Areas so that the diverse group can balance and focus efforts. It is a very diverse group and consists of test tracks, indoor and outdoor facilities small and large. The scopes and objectives of the experiments vary significantly. No two APT experiments are designed to obtain the exact same results using identical loading scenarios; therefore, it is impossible to create a "one-size fits all" construction scenario for all APT facilities. Common construction practices and differences were synthesized and facilities can take from lessons learned by others. Overall the CAPT will be focusing its future efforts towards both the overall coordination of APT research in the United States and the day-to-day activities that are outlined as needs and gaps for all the participants.

Instrumentation needs and gaps, however, is one of the areas that affects all of participants. This includes common installation methods, data collection methods and equipment, and analysis of the data files. Two types of instrumentation has created the most interest from the CAPT members. These include strain and moisture. Pressure cells are seeing greater use. There is a strong need for a hands-on instrumentation demonstration rodeo, but again this is hard to coordinate as a group. Smaller installations at individual facilities along with a coordinated effort from everyone including manufactures maybe more achievable. It will also be beneficial to establish a consensus on instrumentation installation protocols as well as gauge signal instrumentation protocols for dynamic stain, pressure, and LVDT types of sensors. A strain response analysis is poised for a future activity.

A TRB workshop (January 2008) has provided an opportunity to address one of CAPT's Emphasis Areas. The manner in which APT experiments can benefit the development and validation of pavement material and distress prediction models was demonstrated. Conversely, models were also shown to be able to assist in the execution of experiments and in the interpretation of instrumentation in APT experiments.

ACKNOWLEDGEMENTS

The authors of this paper would like to thank the members and associates of the CAPT pooled fund for their support and help with this research; California DOT, Texas DOT, Kansas DOT, Illinois DOT, Minnesota DOT, Indiana DOT, Ohio DOT, Louisiana DODT and Louisiana Transportation Research

Center, Alabama DOT, New York DOT, Florida DOT, US Army Corps of Engineers, University of Illinois, Kansas State University, and Ohio University.

This paper is the views of the corresponding authors and may not reflect the views of each of the CAPT participants.

REFERENCES

Metcalf, J.B., NCHRP Synthesis of Highway Practice 235: Application of Full-Scale Accelerated Pavement Testing, Transportation Research Board, National Research Council, Washington, D.C., 1996, 110 pp.

Saeed, A. and J.W. Hall, Jr., NCHRP Report 512: Accelerated Pavement Testing: Data Guidelines, Transportation Research Board, National Research Council, Washington, D.C., 2003.

Hugo, F. and A.L. Epps-Martin, NCHRP Synthesis of Highway Practice 325: Significant Findings from Full-Scale Accelerated Pavement, Transportation Research Board, National Research Council, Washington, D.C., 2006.

Federal Highway Administration, Transportation Pooled Fund Studies, Solicitation Number 1177, Recycled Materials Resource Center, July 2008(a) <http://www.pooledfund.org/projectdetails.asp?id=1177&status=1>

Federal Highway Administration, Transportation Pooled Fund Studies, Solicitation Number 1175, The Impact of Wide-Base Tires on Pavement Damage: A National Study, July 2008(b) <http://www.pooledfund.org/projectdetails.asp?id=1175&status=1>

University of Nevada-Reno, Final Meeting Minutes of the International Workshop on the Use of Widebase Tires, July 2008, <http://www.arc.unr.edu/Workshops/Wide-Base_Tires/International_Workshop_on_the_Use_of_Widebase_Tires-Minutes-Final.pdf>

Willis, J. R. and R. B. Powell, "A Synthesis of Construction Practices for Accelerated Loading Facilities in the United States," Paper Submitted for Presentation and Publication, *3rd International Conference on Accelerated Pavement Testing*, Madrid, Spain, 2008.

Willis, J. R. and R. B. Powell, "A Synthesis of Practical and Appropriate Instrumentation Use for Accelerated Pavement Testing in the United States," Paper Submitted for Presentation and Publication, *3rd International Conference on Accelerated Pavement Testing*, Madrid, Spain, 2008.

TABLES

Table 1 CAPT Emphasis Areas

Emphasis Area	Goal
1. APT / Test Track Facility and Equipment Advances	To identify future APT equipment and testing capabilities, beyond state-of-the-art. Each facility is constantly looking to improve the current devices they own and operate. In some cases, the current APT technology is over 25 years old, as is the case with the FHWA facility. Additionally, others are learning new ways to build test sections, instrument the APT equipment and to process and store the data. This Emphasis Area will help keep the technology and management of the facility at the cutting edge.
2. Standard APT Terminology and Test Procedures	To develop and maintain an overall procedures/best practice manual for APT/Track owners and operators in order to enable easy transfer and interpretation of data and practices. Attempt to match up with completed work by other organizations, such as EU Cost 347 or AFD40. Collect established procedures from any of the facilities and develop a consensus template.
3. Construction Site Practices and Procedures at APT Facilities	To establish best common APT construction practices. What went right? What went wrong?
4. Gaps and Needs in APT Instrumentation of Pavement, Bases, Subgrades	To develop an overall procedure/best practice for instrumentation in terms of gage selection and data collection / interpretation. This Emphasis Area is linked to Emphasis Area 6, data acquisition and processing.
5. APT Condition Evaluation Techniques and Frequency	To improve current operations and individual experiments and to gain the value from consensus and more uniform practices.
6. APT Data Acquisition, Storage, and Sharing Methodologies	To achieve greater uniformity of data acquisition (i.e. optimum frequency) and storage to increase data access and use among centers.
7. APT Experimental Design and Loading Methodologies	To develop guide methodology or protocol for cooperative experimental designs that will enhance the sharing and interpretation of data among APT owners and operators. The protocol will not be specification, but rather a document that outlines what needs to be considered when developing an experimental design, including the implications of comparison between experiments. This Emphasis Area is intended to expand the experimental design with additional test cells or to or provide a measure of repeatability by overlapping cells.
8. Relation between APT and Theoretical Models for Pavement Response and Distress	Identify best practices in evolving pavement response and distress models
9. Performance Relationships (linkages to LTPP, RTL, etc.)	Identify a protocol to link APT results to field pavement performance (in-service) Tough to do because field failures are risky.
10. Training, Education, Outreach, Economic Analyses	Develop mutually useful training and education documents, accessible and rich websites, economic summaries and contemporary white papers

Table 2 Ranked Interest in Instrumentation for Pavement Condition and Response

Instrumentation Category	Pavement Condition or Pavement Response Type	Priority Votes
Environmental	Moisture	7
	Temperature	4
Primary Response	Strain	9
	Shear Strain	-
	Pressure	6
	Multi-Depth Deflectometer	5
	Surface Deflection	-
	Tire Load (pressure dist)	2
Distresses	Automated Surface Crack Measurements	2
	Measuring Cracking not at the Surface	2

FIGURES

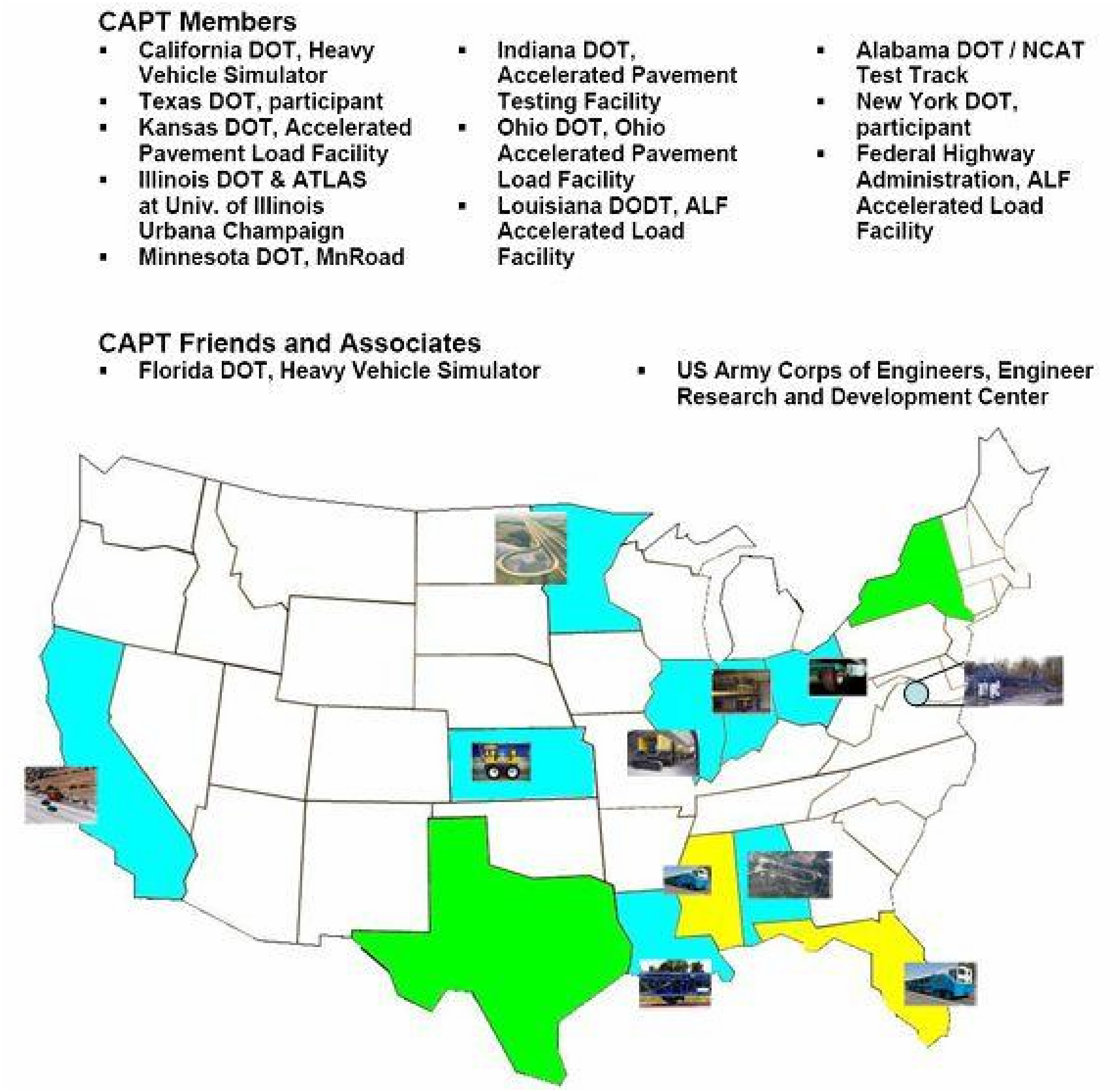

Figure 1 CAPT Participants