MnROAD Observations on Low Volume Roads
MnROAD Lessons Learned – December 2006
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1 Abstract

In its first decade of operation, MnROAD used its 2.5-mile low-volume road (LVR) for extensive experiments and continuous data collection on a variety of test sections. These efforts have lead to a number of benefits to Minnesota roadways and to the larger pavement community. This brief details the low-volume road at MnROAD and the work done using the low-volume road in LVR design, aggregate road studies, and the adoption of new LVR materials. As MnROAD looks forward to its second phase of operation, this brief will provides recommendations for the low volume road and continued benefits of the low-volume road.

2 Background

Though MnDOT has invested a large majority of its research and time into studying concrete and asphalt materials and pavements, this investment does reflect the predominance of concrete and asphalt roads in Minnesota, as approximately 53% of Minnesota's roadways are aggregate roads. Pavement engineers often disregard aggregate roads in their work, despite the long-term service and low maintenance that county engineers expect of these vital roads. Furthermore, the low-volume roadways dispersed throughout the Minnesota's city and counties are often equally unappreciated and under-researched by pavement engineers when held alongside their high-volume interstate and highway counterparts.

Since the planning stages of MnROAD, MnDOT has recognized the need to conduct experiments and collect data on low-volume roads. In the planning document for the LVR, MnDOT wrote of the need to "'fill the pavement knowledge gap' for municpal county, and low traffic volume mainline systems of Minnesota" as a compliment to the extensive mainline (interstate/highway high-volume roads) research. MnDOT's goal in its LVR initiative was not simply as a novelty alongside the larger mainline research, but as part of work on behalf of the transportation community toward "as broad an understanding…of the total pavement material-environmental interaction problem" (MnDOT 1988).

Construction of the low-volume road test facility concluded along with the construction of the mainline, the low-volume road having been constructed as a continuous, two-lane, 2.5-mile loop, pictured below in Figure 1. The 20 test sections on MnROAD's LVR, which is closed to open, "live" traffic, are loaded in a using a five-axle tractor-semi trailer with two different load configurations (80 kip and 102 kip). The 80 kip (or "legal") truck loads the inside lane 4 times per week, and the 102 kip (or "overload") truck loads the outside lane once per week. The desire in doing so is to provide both lanes with as close to the same number of ESALs as possible so that the only difference in loading is the load itself and the number of repetitions. The regular, controlled loading distinguishes the MnROAD LVR from other full-scale pavement facilities.

Figure 1. One end of the MnROAD low-volume roadway's loop

The research done at MnROAD on low-volume roads, while not as "high profile" as other research, is extremely valuable in its influence on local design and maintenance practices, knowledge of materials, and ability to minimize costs in improving local roadways. Only a portion of this research will be detailed in this brief, whose intent is to introduce the reader to MnROAD's low-volume loop, some of the research and reports that have come out of the low-volume loop, and the influence of this research on the greater pavement community. A comprehensive discussion of MnROAD's experience in low-volume roads can be found in "MnROAD Low Volume Road Lessons Learned" by Benjamin Worel, Operations Engineer at MnROAD.

A final note on the background of the low-volume road at MnROAD is the importance of the Minnesota Local Road Research Board (LRRB) in the research operations at MnROAD, especially those operations on the low-volume loop. State legislators created LRRB in 1959 to conduct research in pavements using municipal and county state aid funds. The board consists of ten members: four county engineers, two city engineers, three MnDOT officials, and 1 representative from the University of Minnesota. Since MnROAD's opening, LRRB has been a valuable partner to MnROAD, both as a consistent source of funding and as a basis for project initiatives. Given this level of participation, LRRB obviously has been involved in a great number of notable research projects in MnROAD's first ten years of operation. All of the projects discussed in detail below received funds from LRRB and/or derived their origins from LRRB research initiatives, and many of the other projects conducted on the LVR test sections had LRRB backing as well.

3 MnROAD Experiences with Low Volume Roads

3.1 Low-Volume Road Design

Given the large amount of sensors collecting data and the regular assessments of the pavement and environmental conditions, MnROAD's depth of knowledge of its test sections exceeds that of any other full-scale facility. Whereas other full-scale facilities assess their roads on typically large intervals (yearly), MnROAD continuously monitors the test sections in the ground. While this familiarity is useful for all test sections, for the low-volume road test sections it is especially significant, as very little full-scale, closely controlled observation had been done on low-volume roads up until MnROAD's opening for operations.

The most noteworthy projects to benefit from the wealth of low-volume road data were those involving mechanistic-empirical design. The authors of MnDOT Report 1999-34, "Minnesota Low Volume Road Design 1998," were the first to use the LVR data at MnROAD in a rigorous way: the material property data from the LVR test sections were entered into a mechanistic-empirical design program (the design procedure then known as ROADENT). The calculated strains from the program were compared to the actual strains as captured by the many embedded sensors in the test sections. ROADENT was continuously calibrated in this way so that performance predictions by ROADENT would reflect the performance observed at MnROAD's full-scale LVR test sections.

MnDOT Report 1999-34 recommends that the Soil Factor and R-Value design procedures for low-volume roads be reconsidered, as ROADENT requires a thicker design than the other two for an equivalent roadway. This conclusion was significant for local agencies, most of whom used either the Soil Factor or R-Value design in planning their roadways, and the foundation of this conclusion was, of course, years worth of MnROAD LVR data.

MnDOT Report 2002-17, "Best Practices for the Design and Construction of Low Volume Roads," builds upon MnDOT 1999-34 by updating the LVR design for Minnesota using MnPave, a mechanistic-empirical design software program with its basis in ROADENT but with many layers of additional sophistication. MnPave was developed using MnROAD performance data and, to a lesser extent, data from Minnesota highway sections. (For more information on MnPave, consult the technical brief "Mechanistic-Empirical Design and MnROAD.")

3.2 Aggregate roads

MnDOT Report 1998-24, "An Evaluation of Aggregate and Chip Seal Surfaced Roads at MnROAD," by Erland Lukanen of Braun Intertec and MnROAD Report 2000-29, "Evaluation of Aggregate Sections at MnROAD," by Greg Johnson and David Baker of MnDOT are, taken collectively, a review of the history and performance of the aggregate and chip sealed test sections in the low-volume loop. These reports are very thorough in detailing every aspect of these roadways and are a useful account of MnROAD's experience in aggregate roads. In addition to either reporting or summarizing all of the data and accounting for all material properties, the authors give a narrative account of some peculiarities in loading the sections and monitoring their performance. For instance, if a section were to fail and require blading to repair the roadway, rather than simply flagging a data set, MnROAD engineers would investigate the failure, and these investigations are reflected in the narrative of the report.

The author of MnDOT 2000-29 found that the rate of freezing and thawing under aggregate roads was much different than the freezing and thawing under HMA sections at MnROAD. The subgrade under aggregate sections froze approximately 4 to 5 days sooner than the subgrade below the HMA. Furthermore, the subgrade under the aggregate sections took between 11 and 35 days longer to thaw than the subgrade under the HMA.

The author of MnDOT 1998-24, based on MnROAD's experience in aggregate roads, makes a number of interesting conclusions and recommendations. The first comment is on the nature of full-scale testing itself: the author found that the true measure of the aggregate sections' performance was their ability to allow the loading truck to pass unimpeded. When the truck could no longer maintain its 30 mph speed on any single section, all aggregate sections (in addition to the section causing the problem) would be bladed to avoid safety concerns for the operator of the truck. Hence, the phenomena that most affected performance in the manner detailed above, rutting and washboarding, were naturally the most closely studied modes of deterioration. The severity and frequency of these phenomena limited the observations due to the fact that when one section approached "failure" in terms of the safety concerns for the truck operator, all sections and ongoing observations were subsequently reset.

Despite this limitation, the author found a strong relationship between washboarding and the number of truck passes. Due to this relationship, more washboarding occurred in the 80 kip lane than in the 102 kip lane. Forensic cross-sections of the sections revealed that the rutting experienced occurred in the aggregate and not the subgrade. The author also found that the use of the chip seal reduced the likelihood of washboarding, though a comparison between the sections suggested nothing conclusive as regards chip sealing and rutting. The author concludes by noting that aggregate gradations are not reliable predictors of performance in an aggregate road.

[It is worth repeating that MnDOT Reports 1998-24 and 2000-29 are very valuable to pavement engineers interested in MnROAD's experience in aggregate roads, especially seeing as how the data from the load sensors was after the replacement of the aggregate sections.]

3.3 Oil Gravel

Through its first ten years, MnROAD has developed test sections with a number of experimental techniques and materials, and its experience with one material in particular, emulsified oil gravel, is unique to test tracks. This experience came about through a long-lasting partnership with the Finnish National Road Administration (FINRA), which has been building roads with oil gravel since the late 1950s. The oil gravel, which consists of a softer binder than a typical hot mix asphalt (HMA) mix, is a flexible thin typically exhibits a long life and low amount of cracking in Finland. In the spirit of collaboration and exploration, MnROAD implemented oil gravel on three test sections in the low-volume loop.

One of the sections (Cell 26) showed distresses shortly after construction, but a forensic trench study of the section suggested that the distress was due to the strength of the base material and not a fault of the oil-gravel surface. This finding is line with FINRA's observations and analysis of oil gravel, which maintain that the oil gravel does not improve the load-bearing capacity of the pavement system. The forensic trenching of this section is detailed by MnROAD engineers in the unpublished report "MnROAD Cell 26 Forensic Investigation."

While Cell 26 was eventually replaced, two of the original three oil-gravel sections remain at MnROAD. These sections have performed very well, and unlike their HMA counterparts, have resisted thermal cracking entirely. The performance of these sections is detailed in an unpublished report from 1999 for the MnDOT Office of Materials and Road Research, "Low Volume Road Construction with Oil-Gravel," and in a TRB report prepared by MnDOT engineers, Minnesota's Experience with Thin Bituminous Treatments for Low-Volume Roads. Finally, MnROAD engineers recently prepared an unpublished summary brief of MnROAD's experience in oil gravel titled "Performance of Oil Gravel Test Sections in Minnesota."

3.4 Miscellaneous projects

It should be noted again that MnROAD's low-volume road projects are far too varied to condense and summarize in a single brief. In low-volume concrete pavements, MnROAD researchers have investigated joint faulting in doweled and undoweled low-volume pavements, the use of a thin concrete surfacing as part of rehabilitation (whitetopping), and the seasonal response of thin concrete pavements to loading. In low-volume asphalt pavements, MnROAD projects have included forensic studies of rutting in test cells and the performance of HMA sections using the Superpave asphalt binder. A number of non-pavement issues have been raised by private corporations (3M, tire company, etc) and MnDOT and the University of Minnesota (some of which are detailed in the technical brief "Non-pavement research"). For more information on the many uses of MnROAD's low-volume road, consult "MnROAD Low Volume Road Lessons Learned," a paper for the 9th International Conference on Low-Volume Roads by Benjamin Worel, Operations Engineer at MnROAD.

4 MnROAD Contributions to Low Volume Roads

In both MnDOT's hands-on LVR experience via MnROAD and MnPave's foundation in MnROAD expertise and data, the current state-of-the-art in low volume road design in Minnesota owes much of its sophistication and reliability to the innovations brought about by MnROAD. One of the most important contributions to MnPave by MnROAD, aside from the fact that MnROAD engineers developed, is that an overwhelming amount of the pavement performance data used to develop MnPave came from the MnROAD test sections. In addition to its use in MnDOT's MnPave, MnROAD data is also being used to calibrate the 2002 Design Guide for low-volume roads.

MnDOT 1998-24 detailed an important lesson (which MnDOT 2000-29 later recounted) in attempting a full-scale test on an aggregate road: a major difficulty is that the loading used by MnROAD for its LVR test sections is not compatible with aggregate roads if the researcher desires to replicate in-field loading conditions for a typical low-volume aggregate road. Instead, the loading at MnROAD for its aggregate test sections resembled that of a construction haul road. For this reason, MnDOT 1998-24 and 2000-29 concluded MnROAD's involvement in full-scale aggregate roads, and during 1999 MnROAD replaced the aggregate sections with SuperPave, oil gravel, and PCC low-volume roads. The discovery of the shortcoming of the full-scale aggregate roads is another instance of MnROAD as a pioneer on behalf of other full-scale test tracks and the pavement community at large.

MnROAD has also acted as a test site for new and potentially beneficial materials for low-volume road construction. MnROAD's experience in oil-gravel roads combined with the remainder of MnDOT's experience with oil gravel throughout the state has helped to educate municipal and city engineers about oil gravel, a new pavement technology for road rehabilitation that would have gone unexplored had it not been for MnROAD's partnership with FINRA.

5 Conclusions and Recommendations

One major benefit of the low-volume road test cells at MnROAD is the fact that no other test track investigates low-volume roads to the extent of MnROAD. Along with its experience in areas such as cold-regions research (including low-temperature cracking) and whitetopping, MnROAD has established itself as an important facility in furthering low-volume road research and construction techniques.

A recommendation is to actively promote MnROAD's experience in low-volume roads. One easy means of increasing the visibility of LVR work is through publishing LVR reports in more easily accessible areas. Many of the resources for this brief are unpublished internal documents that, with superficial editing to meet publishing guidelines, could easily be TRB papers, MnDOT library documents, or conference proceedings.

A final recommendation is that MnROAD continue its efforts with LRRB, who has been instrumental in initiating and supporting LVR research. With the help of LRRB, MnROAD can continue to provide the pavement community with quality research in low-volume roads. As very few research is done in this field to begin with, this is another opportunity for MnROAD to distinguish itself and promote itself as the nation's premier test track.

6 References

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