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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

INNOVATIVE GUARD RAIL PLACEMENT

by Steve Golding, P.E., and Kathleen Jones
Division 10, Research Section

District 11, Lufkin, is enthusiastic about a new method for constructing guard fences. During the 1988 construction season, the District contracted to have 18,946 feet of guard rail on SH 147 removed and replaced. The contract was let with an estimate of the percentage of reusable rail, but stipulated the use of new nuts, bolts, and posts. Marcus Construction Corporation, an out-of-state firm with a regional office in Cedar Hill, Texas, underbid all the conventional-method operators with a highly efficient, innovative construction method. With a crew of four to five and a truck-mounted drilling and pile-driving rig, this contractor was able to *remove and replace* 1000 feet of rail per day. (The average conventional-method crew of five might be able to remove and replace around 500 feet per day.) Reusable rail in the 18,946 feet was estimated at 80 percent. Marcus' bid was 50 cents a lineal foot to remove old rail, and \$9.00 a lineal foot to place new.

Currently, many contractors drill or excavate holes much larger than the diameter of the posts, align the rail on jigs (hangers), then attach the posts to the rail and backfill the postholes. Often with this method, the posts are difficult to keep in alignment as

FIG.1: Truck-mounted drilling and pile-driving rig.

Drawing from videotape

INSIDE...

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they are being backfilled; this sometimes results in poor alignment of the rail. Another problem with this method is that the posts settle unevenly over a period of a few months, pulling the rail out of alignment. The new method overcomes both of these problems by aligning the rail first on hangers, pile driving the posts into holes near to, or slightly smaller than, post diameter, and then attaching the rail to the posts. Little or no backfilling is necessary.

After each 25-foot section of rail is placed on a pair of jigs (hangers) in proper horizontal and vertical alignment, a truck with a trailer load of posts follows. A crew unloads four posts per section to the back of the rail. Next in the sequence is the truck-mounted drilling and pile-driving rig.

The operator drives the rig along the guard rail, until the person on the ground, who places the posts, signals to the operator to stop. The post placer helps the operator position the auger so it aligns with a bolt hole in the rail. A hole, slightly smaller than the post, is drilled. The post placer picks up a post and sticks a metal rod through the hole in the post. He then positions the post onto the posthole. The operator uses the pile driver on the rig to drive the post. The post placer stops him when the metal rod in the post comes to the correct elevation. The post placer removes the metal dummy and pushes the actual bolt through the post and rail. He hand-tightens the nut at the back. A third crew member follows with a power torque wrench tightening the bolts on the posts and lap slices. A fourth crew member checks the soil at the base of the posts, tamping it with a shovel when necessary.

The procedure is very precise, with no time wasted trying to bolt a rail to a post that is too far away. It takes about one minute to drill the posthole, drive the post, and then bolt the post to the rail. District 11 videotaped segments of the construction method. Watching the videotape, through many consecutive post settings, it is obvious that this procedure worked very well. Every post was placed quickly and accurately, without a single post having to be pulled up. For more information, contact Mr. Walter Hearnsberger, San Augustine Resident Engineer, District 11, (409) 275-2541. A copy of the unedited, un-narrated video footage is available on loan from the D-10R Technology Transfer Library, TEX-AN 241-7644, (512) 465-7644.

FIG.2: Aligning auger with rail hole.

Drawing from videotape

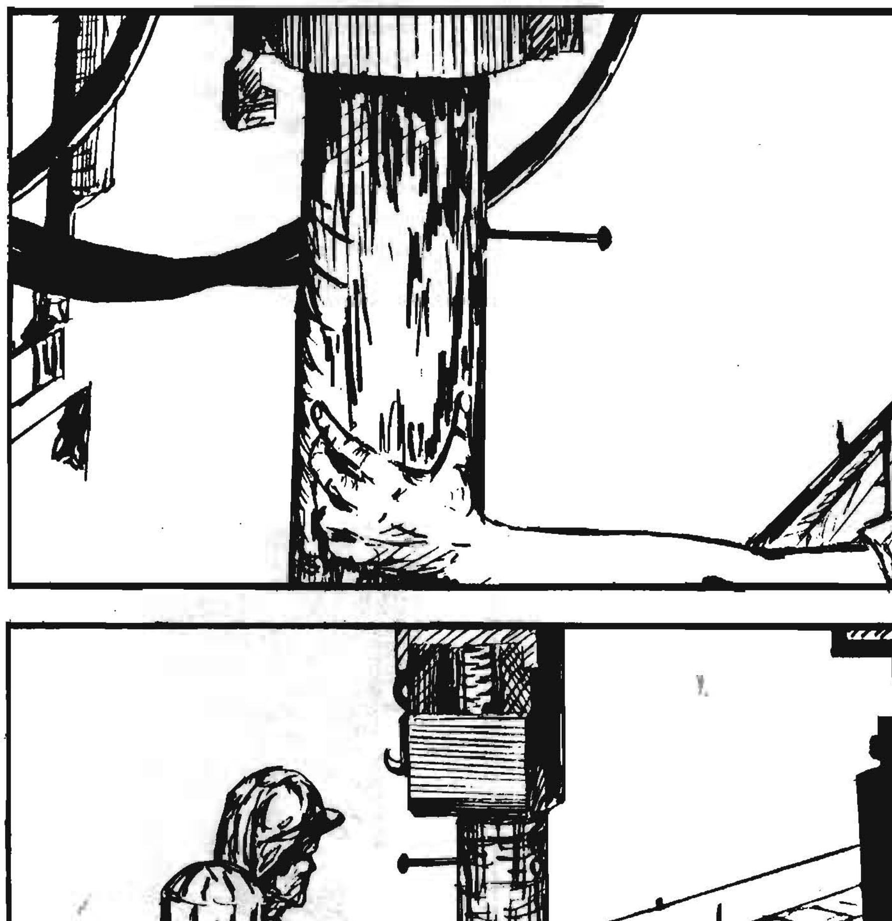

FIG.3A & B: Driving the post to correct elevation.

ELECTRONIC TAG IS MADE IN AUSTRALIA

The electronic license tag affixed to cars in the Hong Kong congestion pricing experiment (AITO:4:86) was made in the U.K. A competing version seeking world-wide applications has now been developed in South Australia, a part of the world noted for its public transport innovations. The proprietary "TransiTag" electronic vehicle identification system, consists of a fixed onboard transponder device which can be interrogated from remote locations to provide a unique vehicle identity code and operational data such as the current mileage reading. It is also possible to obtain variable data, such as the load content, weight, destination and driver identification, to build the essential components of a computerized fleet management system. The electronic license plate makes possible the automation of fuel dispensing, weigh bridges, parking garage access and timekeeping. In the case of public transport and emergency services, the developers of the TransiTag system note that it can be interlocked with traffic light controllers to provide intersection priority for buses, ambulances and police cars.

As in the Hong Kong demonstration, the TransiTag transmits its code and data as it passes over a detector loop. A roadside interrogator unit decodes the message and converts it into a computer-readable format which can be sent over a phone or cable system to the fleet management mainframe.

*From **AASHTO International Transportation Observer**, Washington, D.C: The American Association of State Highway and Transportation Officials, April 1987. Used by permission.*

PILE DRIVING HAZARDS

There are certain hazards associated with pile driving of which field personnel must be aware in order to avoid injury or more serious consequences. The following safety precautions are taken from SDHPT Construction Bulletin C-8, Pile Driving Manual:

FIGURE 1: Are you at risk?

1. Be certain that boiler and steam or air lines are in good operating condition and do not continuously stand near them as they may fail causing serious injury.
2. Stand clear of the driving rig while it is being moved or set up.
3. Stand clear while piling are being hoisted into position for driving.
4. Always wear safety helmets, safety goggles and any other safety gear that will protect against injury while working under the rig during driving operations.

In addition to the above, working under a rig should be avoided by inspection personnel if at all possible. Pieces of concrete or steel have been known to spall from piling, driving helmets, hammers, etc. while piling are being driven. Such falling pieces have been known to cause serious injury and even death. Inspection personnel should arrange their work to avoid working under pile driving rigs where the risk of injury is great. It is recommended that penetration readings be taken with the aid of a transit or level set up a safe distance from the rig. Various methods have been used to accomplish this, such as taking readings from a gauge attached to the pile or hammer or by marking the pile with increments to be used for taking penetration readings.

Sometimes it might be necessary to work within a cofferdam. If so, try to perform the necessary work or measurements from the area farthest away from the rig to avoid falling objects; but if at all possible try to perform all inspections from outside the cofferdam when driving operations are in progress. Ear plugs should be used when working within a cofferdam to prevent injury to the ears by the loud noises caused by driving. Stay alert and look for signs of failure or other hazards which may cause injury; if any are noticed, alert workers and any other persons of the danger; stop the driving operations if necessary until the hazard is removed. Play it safe!

From *SDHPT Bridge Tips*, No. 1 (13 DECEMBER 1985), published by the Bridge Division (D-5) of the Texas State Department of Highways and Public Transportation.

GEOTEXTILE WALLS REDUCE BRIDGE MAINTENANCE COSTS

by John T. Price, P.E.
Price and Company, Inc.
Wyoming, MI

An innovative use of geotextiles by the Wyoming Highway Department has significantly reduced their bridge maintenance costs. Since 1983, forty-five Interstate, State primary and State secondary structures have been constructed or retrofitted with geosynthetic reinforced soil (GRS) walls beneath each approach slab. Geotextile inclusion enabled soil support continuance beneath the slabs and prevented or significantly reduced lateral soil pressures against the adjacent abutment walls. The result: (1) not one of the 90 approach slab-bridge deck junctions has required "leveling" to improve serviceability and safety, and (2) none of the expansion joints have required replacement due to closure as a result of abutment movement.

PROBLEM IDENTIFICATION — APPROACH SLAB

Correcting bridge end "bumps" represented a costly maintenance program to the Wyoming Highway Department (WHD). For years, the WHD addressed this problem by placing leveling courses above the approach slabs. When required, mud jacking was used to fill voids between a slab and embankment soil. Both treatments offered limited success as continued maintenance was required — at an **annual** cost of over $1,600 per bridge wherever the slab/deck unconformity occurred (1985 figure).

The continued drain on the Department's budget prompted an investigation to review alternatives. The investigation concluded that a method was required to prevent a loss in soil support beneath the approach slabs, i.e., **treat the cause of the problem** as opposed to mending a surface condition resulting from the problem. Unfortunately, the soil support loss had several origins, among which were (1) densification of the embankment soils as a result of traffic vibrations, (2) consolidation of the embankment soils, and (3) piping of the embankment soils into the subgrade drain system or through joints or cracks in the structure. Consolidation of the foundation soils was deemed negligible due to their type and strength. Therefore, the remedial method had to address three origins of soil support loss. After reviewing available alternatives, GRS walls were chosen as the preventative measure based on reliability, cost, flexibility (to account for site-specific constraints) and ease of installation.

PROBLEM IDENTIFICATION — EXPANSION JOINT

Expansion joint closure or reduced movement had been a troublesome and costly problem for the WHD. At a replacement cost of approximately $25,000 for each device (1985 figure) and a frequency greater than expected, the WHD again reviewed the problem causes and available correction alternatives. Their review indicated that a contributing agent to expansion joint failure was abutment movement resulting from lateral soil pressure. Since GRS walls could provide total lateral soil restraint and were already planned for use beneath adjacent approach slabs, they were considered the best solution to eliminate this origin of expansion joint failure.

DESIGN TECHNIQUES AND CONSIDERATIONS

Using the guidelines presented by Steward, et al.[1], the WHD analyzed walls having configurations similar to those shown in Figure 1 (reprinted from working drawings). Steward's approach uses conventional geotechnical design assumptions and is suitable to design structures both with and without wing walls. Figure 2 provides a three-dimensional schematic of a geotextile configuration for wing wall type structures. The WHD designed each GRS wall to account for local geometry (fill height, foundation soil/rock slope, surface contours, etc.), soil conditions and live loads. Because this analytical method does not account for the composite effect of multiple reinforcing layers, conservatism inherently results. Full-scale

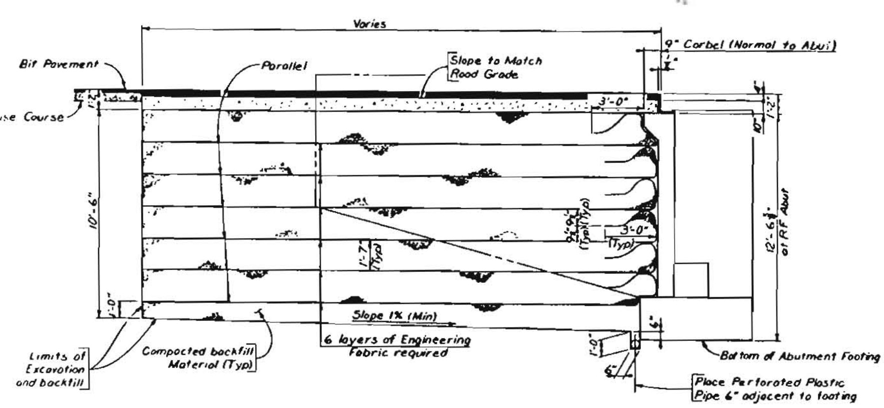

FIGURE 1: Representative wall configuration.

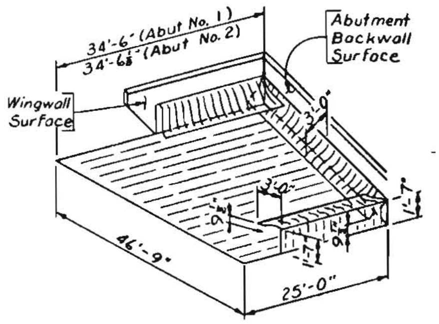

FIGURE 2: Typical Layer of Fabric (Near side wingwall not shown for clarity).

field research[2] verifies this conservatism.

In essence, the analysis provides direction to the following unknowns: (1) number of reinforcing layers required; (2) tensile strength necessary for each reinforcement member; (3) length of each reinforcement member; and (4) distance between reinforcement layers. These four design elements are mutually dependent — altering one has an effect on the others. Once the wall elements are determined, the composite structure of soil and reinforcement material is analyzed as a rigid body for resistance to rotational and sliding failures. Finally, a review of the foundation soil's bearing capability is made.

While the Steward approach provides details of wall component placement and structural requirements, several incalculable benefits are derived from using GRS walls. Specifically, multiple reinforcement layers significantly increase the overall fill stiffness[3]. With greater stiffness, better compaction is possible and less traffic-induced settlements result. The increased density also translates into greater shear strength for cohesionless soils. Therefore, loads are distributed more quickly and evenly, reducing differential consolidation. Geotextiles placed as shown in Figure 1 confine, separate and filter the embankment's cohesionless soils. Migration of particles into the subsurface drain systems or through joints in the structure is prevented. Therefore, GRS walls inherently prevent this contributing cause of soil support loss.

GRS walls are normally constructed without the presence of abutments or wing walls; they have the capability to sustain all lateral soil pressures. However, soil movement is required to activate the reinforcement member's tensile strength. Research[3] at Glenwood Canyon, Colorado, indicates that less than 3 inches of lateral soil movement is necessary to stabilize a 15-foot high GRS wall in an unrestrained (no abutment) condition. Since one of the WHD objectives was to achieve an unrestrained condition (no soil pressure on the abutment), 3-inch thick polystyrene panels were placed between the geotextile and abutment (or wing wall). The panels would compress with lateral soil movement and reduce or eliminate soil pressure against the abutment and wing wall.

CONSTRUCTION

For both retrofitted and new structures, the abutment and wing walls were used as "forms" for constructing each reinforced lift. As shown in Figure 1, the foundation soils were prepared by cutting a slope toward the abutment footing. An underdrain system (pipe and drain stone) was placed, bringing the fill height to approximately the height of the abutment footing top. Three-inch thick polystyrene boards were positioned on the soil side of the abutment and wing walls. With the styrene in place, the first geotextile layer was positioned. The re-embedment "tail" of the geotextile was temporarily tacked to the polystyrene to allow subsequent fill placement and compaction. Granular fill was then placed and compacted to a depth equal to one-half the distance between the reinforcement layers, except immediately adjacent to the abutment and wing walls. At these locations, the full depth of fill (between geotextile layers) was placed. The embedment "tail" was then positioned and the remaining fill added to achieve proper elevation (to the level of the next geotextile layer). This embedment "tail tucking" procedure was used to enhance geotextile-to-soil friction and thus reduce the possibility of a local reinforcement member "pull-out" failure. The sequence of geotextile-fill placement was repeated until the approach slab elevation was achieved.

COSTS AND BENEFITS INVOLVED (1985 FIGURES)

Once the foundation soils were prepared, the installed cost of the geotextile reinforced system was approximately $12,000 per bridge or $6,000 per end. For comparison, a conventional, un-reinforced approach slab embankment typically costs approximately $3,200. The $2,800 difference was attributed to additional granular fill requirements and geotextile costs as well as increased construction time requirements.

Justification for this initial capital outlay resulted from elimination of the $1,600 annual maintenance cost for "leveling" at many locations. Public convenience and increased safety contributed significantly to offset the cost differential. Finally, the elimination of the replacement of just one explansion joint offset the increase in construction cost of eight GRS walls. Therefore, geosynthetic reinforced soil walls were considered justified and have become the design alternative preferred by the Wyoming Highway Department for approach slab embankments.

CONCLUSIONS

Forty-five Wyoming bridges (90 approach slab embankments) have been constructed or retrofitted with geosynthetic reinforced soil walls since 1983. The structures have withstood a wide range of internal and traffic loadings. Since the installation of the GRS walls, the Wyoming Highway Department has not made repairs to any of the 90 embankments or approach slabs as a result of soil support loss. Similarly, the State has not been required to replace any expansion joints associated with these bridges.

COMMENTS

The use of geosynthetic reinforced soil walls is an effective means to reduce approach slab and expansion joint maintenance costs. The Federal Highway Administration and U.S. Forest Service as well as many State transportation departments recognize GRS walls as a genuine tool for use by engineers. Since the initial WHD installations and the subsequent cost figures reported previously, more realistic (less conservative) analytical tools are now available which reduce the strength and embedment lengths of the reinforcement members. Therefore, significantly lower cost walls may be constructed. Geosynthetic reinforced embankments may be properly constructed by contractors inexperienced in this application.

An update from the Wyoming State Highway Department's Chief Engineering Geologist, W.F. Sherman, P.E.:

"We utilize the fabric reinforced design in areas where settlement is anticipated within the fill. We do not utilize the reinforcement where the settlement is in the foundation below the fill or where the fill material is not susceptible to settlement.

"At the present time the University of Wyoming has instrumented an installation west of Cheyenne for the Department. This project was completed last fall [1987] and we have received no definitive information at this time."

Dr. Tom Edgar of the University of Wyoming is the research contact for this project. The D-10R Technology Transfer Library has been placed on a list to receive data on the project as it becomes available.

REFERENCES

1. Steward, John E., Williamson, R., and Mohney, John, ***Guidelines for Use of Fabrics in Construction and Maintenance of Low-Volume Roads,*** United States Department of Agriculture, Forest Service, Portland, Oregon; June 1977.
2. Guido, V.A., Chang, D.K., and Sweeney, M.A., ***Bearing Capacity of Shallow Foundations Reinforced With Geogrids and Geotextiles***, Preprint Volume, Second Canadian Symposium on Geotextiles and Geomembranes; Edmonton, Alberta; September 1985; pp. 71-78.
3. Bell, J.R., Barrett, R.K., and Ruckman, A.C., ***Geotextile Earth Reinforced Retaining Wall Tests: Glenwood Canyon, Colorado***, Transportation Research Board; Washington, D.C.; January 1983.
4. Price, John T. and Sherman, William F., "Geotextiles Eliminate Approach Slab Settlement," ***Public Works,*** Volume 117, No. 1, January 1986, pp. 58-59.

EDITOR'S NOTE

The author of "Geotextile Walls Reduce Bridge Maintenance Costs," John T. Price, is a well-respected civil engineer specializing in Geotechnical Engineering. He presents either design or informational workshops on geotextiles and geosynthetics. The design workshops are geared primarily toward project engineers. The informational ones focus on giving a detailed introduction to the design and installation aspects of using geosynthetics. If enough Departmental personnel express interest, Mr. Price could come and give a workshop on using geotextiles to reduce approach slab fill settling. If you are interested in such a workshop, call the ***TQ*** editor, Kathleen Jones at TEX-AN 241-7947, (512) 465-7947, and say so.

TROUBLESHOOTING HIGH-RANGE WATER-REDUCERS

by Kathleen Jones
D-10 Research Section
Technology Transfer Group

INTRODUCTION

High-range water-reducers (HRWR), also known as superplasticizers, are chemical admixtures which can be added to portland cement concrete mixtures to produce high slump concrete, or to produce high strength (above 6000 psi) concrete, depending on the mix proportions. HRWRs increase workability by dispersing individual cement particles through the paste. Because they increase workability, superplasticizers are capable of reducing the water content of a concrete mix by 15 to 30 percent without reducing slump or of producing a high slump in concrete without changing the water/cement ratio. HRWRs differ chemically from regular water reducers. The three primary materials from which HRWRs are made are:

1. sulfonated naphthalene formaldehyde condensates;
2. sulfonated melamine formaldehyde condensates; and
3. modified lignosulfonates.

All superplasticizers must meet ASTM C 494 Type F or Type G standards. By definition, admixtures of these types reduce the quantity of mixing water required to produce concrete of a given consistency by 12 percent or greater. Type F does not retard the set. Type G does retard the set [2]. At the moment, only Type F has been tested and approved by Materials and Tests Division (D-9).

Although relatively expensive (the total cost of a superplasticizer may be as high as $4.00 per yard of concrete in a typical 5-sack mix), superplasticizers can yield economic benefits in certain types of applications [1]. HRWR concretes, in general, offer higher strengths and lower permeabilities than can be had with conventional concretes. Also, they are often more abrasion resistant [1]. HRWR admixtures should ***never*** be used as a substitute for good concreting practice, however.

Good concreting begins with a good, plastic mix design. Avoid harsh, rocky mixes. Rocky mixes don't superplasticize well and will be prone to segregation, bleeding, and honeycombing. Optimum coarse and fine aggregate factors need to be selected and tested in trial batches using representative job materials. Another major problem which may be encountered using superplasticizers is unusually "rapid slump loss," which really means a sudden loss of workability within what should be acceptable placing time. The rapid slump loss appears to be an inherent difficulty with ASTM Type F admixtures. It can be controlled, but not eliminated, by some practical steps explained later in the "Guidelines" section.

To encourage good concreting practice, the Department has included the following data note on the special provision sheet to Item 437: "High-range water-reducers will be used only to meet special requirements and will require the written approval of the Engineer on each specific project. A satisfactory work plan for control shall be submitted by the Contractor for approval, and evaluation of the concrete containing the admixture will be performed by the Engineer." Certain guidelines must be followed and a work plan must be developed for each job (to cover natural variations in chemistry of different mix materials and differing job conditions) to avoid major problems associated with the use of HRWR. This article will give a brief account of some typical HRWR applications and will outline information and provide guidelines for developing a suitable work plan for its use.

APPLICATIONS

Some main applications of HRWR are:

I. *Adjusting strength.*

1. Increasing the strength of a 4- to 6-sack concrete mix without increasing cement content. The water-reducing capacity of superplasticizers is used to produce a high strength concrete of normal workability from standard, good quality materials (Fig. 1).

2. Producing workable, high strength concrete (greater than 6000 psi) with very low water/cement ratio, with an increased cement content (a 7- to 9-sack mix), and with no exotic materials such as silica fume. Water content can be reduced by up to 30 percent. In fact, concretes with water/cement ratios as low as 0.28 have been designed and placed successfully [3, p235].

Precasting of prestressed elements is an area where special high strength requirements often occur (Fig. 2). High strength mixes achieve release strength earlier allowing earlier form removal, resulting in increased production and reduced fuel costs associated with steam curing.

II. *Adjusting slump without increasing water content.*

1. Producing high slump, normal strength concrete. The cement-particle-dispersing properties of superplasticizers enable the mix to be made more workable without changing the water/cement ratio.

2. Producing high slump, high strength concrete. Superplasticizers can be used with high strength mix designs to increase the workability from stiff through normal to extremely plastic.

Fresh high slump HRWR concrete is cohesive and can be consolidated with limited vibration — two useful properties in a prestressed casting operation. High slump, high strength con-

FIGURE 1: A possible application for stronger-than-average concrete: Bridge rails to contain and redirect 80,000 lbs trucks.

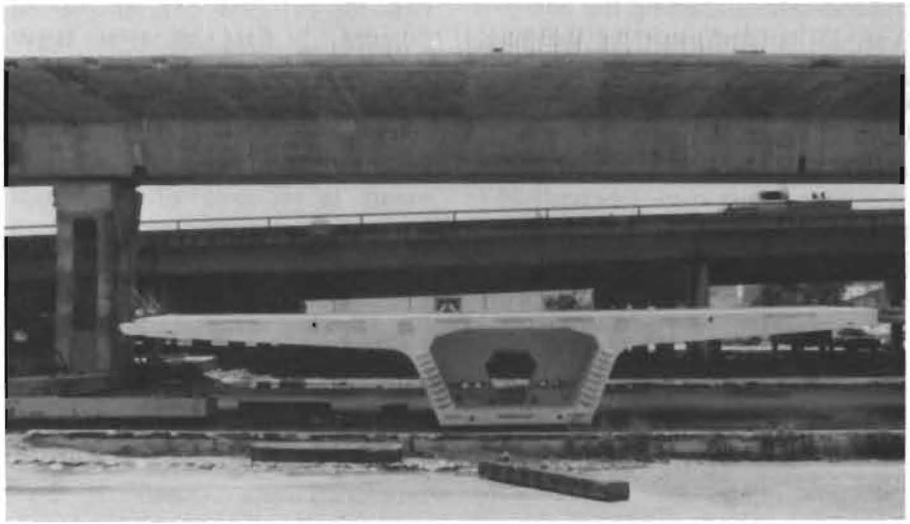

FIGURE 2: Y-wing segmental bridge in San Antonio. Most precast, prestressed elements were cast using HRWR high strength concrete.

crete is especially useful in bridge structures which have heavily congested steel reinforcement. Research shows that the addition of a superplasticizer can raise the steel-concrete bond strength in both normal and lightweight concrete [3, p250]. Fine dispersion of cement particles makes the increase in bond strength possible.

HRWR can be used in many applications such as the production of lightweight concrete, concrete containing fibers, fly ash concrete, pumpable concrete for underwater placement, and blast furnace slag concrete; however, HRWR should be used only when necessary to meet a specific need.

TROUBLESHOOTING

HRWR concretes are frequently more difficult to handle because they can suffer rapid loss of workability. Do not attempt to correct rapid slump loss by the addition of retempering water, by over-vigorous finishing, or by use of water as a finishing aid. Trying to achieve an adequate-appearing surface in this way will only harm the durability of the critical top quarter-inch. Try to avoid rapid slump loss and other problems by following these guidelines:

- *Avoiding Rapid Slump Loss*

1. Estimate a reasonable transit time from the location of the ready mix plant to the job site. Use this estimate to establish a time for the initial dose of superplasticizer to be added to the fresh concrete. (The HRWR is to be added to the concrete at the job site within a certain time, as specified by the work plan, to aid in controlling rapid slump loss.) [1].

2. Add retarding admixture at the plant if the reasonable time for addition of HRWR is estimated at more than 30 minutes.

3. Evaluate the trial batch slump test results, plotting a slump-loss-versus-time and a temperature-versus-time curve. Limit ready mix truck loads to a volume that may be placed and consolidated within the time frame for continuing acceptable workability as determined by the slump-loss-versus-time and the temperature-versus-time curves. To ensure adequate mixing, it is recommended that the ready mix trucks will need to be limited to 75 percent of their rated capacity [7].

4. Loss of workability is lessened at lower temperatures [3]. During hot weather, retarding admixtures should be used with superplasticizers. Retarders help offset rapid slump loss by slowing the initial set [1]. Also, if changing conditions threaten to raise the concrete temperature above the work plan's specified maximum, hot weather concreting measures have to be taken to ensure that the concrete mix temperature remains at or below the maximum.

5. Redose the fresh concrete with HRWR if it does not reach design slump with the initial dose (this ***does not*** apply to air-entrained mixtures). With the exception of air-entrainment, a second dose of superplasticizer will not harm concrete properties. It may, however, extend the setting times noticeably. This would not be a problem with formed finishes, such as columns [1]. The concept of a sequence of doses at specified intervals (determined during trial batching) is useful in avoiding rapid slump loss during hot weather HRWR concreting [3, p239].

6. Plan placing and finishing operations for maximum efficiency. Quick, competent handling avoids leaving concrete waiting in the mixing trucks. The less time that passes, the less time the concrete has to stiffen.

- *Avoiding Segregation, Bleeding, and Finishing Difficulties*

1. Design a mix that is appropriately proportioned for the intended superplasticizer application. To prevent bleeding in lean to medium cement-content mixes, an increase in sand-to-total-aggregate is usually necessary. In rich mixes, the normal ratio is usually satisfactory, but if the trial batch is sticky and difficult to finish, a slight decrease in sand-to-total-aggregate ratio may eliminate the problem [4, p33]. Failure to achieve an optimum fines content may result in segregation and obvious bleeding [3, p230].

2. Use the *minimum* amount of HRWR needed to achieve the specified w/c ratio and slump. The dosage to attain a given slump will depend, in part, on the initial slump. Mixes with low intial slumps of 1 to 2 inch will require higher dosages of HRWR

than will mixes with greater initial slumps. In general, the slump gain increases as the amount of HRWR increases, up to a maximum effective dose. Past this dose, increases in superplasticizer do not yield more benefit [3, p228]. Excessive amounts of HRWR, in addition to being uneconomical, may result in segregation, bleeding, and loss of entrained air [8]. Excess superplasticizer bleeding to the surface will leave an oily residue that will not allow another layer of concrete to bond properly. The surface of an over-superplasticized mix may also show unusual crusting.

3. Keep in mind that HRWR high slump concrete responds very quickly to vibration. Vibration should be kept to the minimum necessary for adequate consolidation or overvibration may result [8].

- *Avoiding Undesirable Chemical Admixture Interactions*

1. Concrete must be thoroughly mixed before adding HRWR or the HRWR will be absorbed irreversibly, leaving only small amounts to act properly as a dispersant. Add any hold water specified by design *before* the addition of the HRWR. After the addition of hold water, the concrete should be mixed a specified minimum number of revolutions [1]. Introducing HRWR after all the mix water has been added insures that the correct amount of admixture will be left in solution to cause dispersion and raise initial slump to the desired slump [1;3, p219].

2. Be aware that naphthalene-based superplasticizer can significantly reduce the effectiveness of neutralized vinsol resin and other specifically developed air-entraining agents. In high slump concrete, it is often more difficult to retain entrained air. If air loss is a problem, it may be necessary to reproportion the mix to achieve the desired results [1].

- *Maintaining Quality Control*

1. Use approved D-9 sources to assure that cement, aggregates, and admixtures have consistent physical and chemical properties.

2. Inspect all mixing trucks prior to use. Trucks with worn blades, build-up on mixing blades, or other deficiencies that will reduce mixing efficiency should ***not*** be used to mix HRWR concrete [8].

3. Disperse HRWR onto the bulk of the mix, rather than the blades of the mixer, by using a rigid extension attached to the dispensing hose [1,2].

4. Conduct intermittent slump and air content tests, monitoring fresh concrete temperature, and casting cylinders and/or flexural strength beams. These tests will detect a temperature rise in the concrete, and will ensure that minimum strength specifications are met [1].

5. Mix the concrete thoroughly, for the amount of time specified by the work plan, after the addition of superplasticizer. Placement should begin immediately.

6. Use standard, good concreting practice throughout.

WORK PLAN DEVELOPMENT

The main objective in developing a detailed work plan is to establish a procedure and practice that will allow the consistent production of superplasticized concrete in agreement with the concrete specifications and specific conditions of the job, including materials selection, proportioning, batching, mixing, and casting. The developed work plan should include the following [from reference 2, unless otherwise indicated]:

1. *Purpose/Reason for using a superplasticizer.* Here, the contractor will justify its use.

2. *Information relating to the materials and concrete mix design.* Proposed procedure recommends that the contractor/supplier should prepare and test small volume batches containing HRWR and record this information in a manner similar to Figures 4 and 5; specification slump range should be used. It is desirable that a SDHPT representative witness these tests. Note: A small portable-type mixer capable of mixing enough concrete to perform the tests outlined in Figures 4 and 5 should suffice. Materials and Tests Division (D-9) recommends a mix-

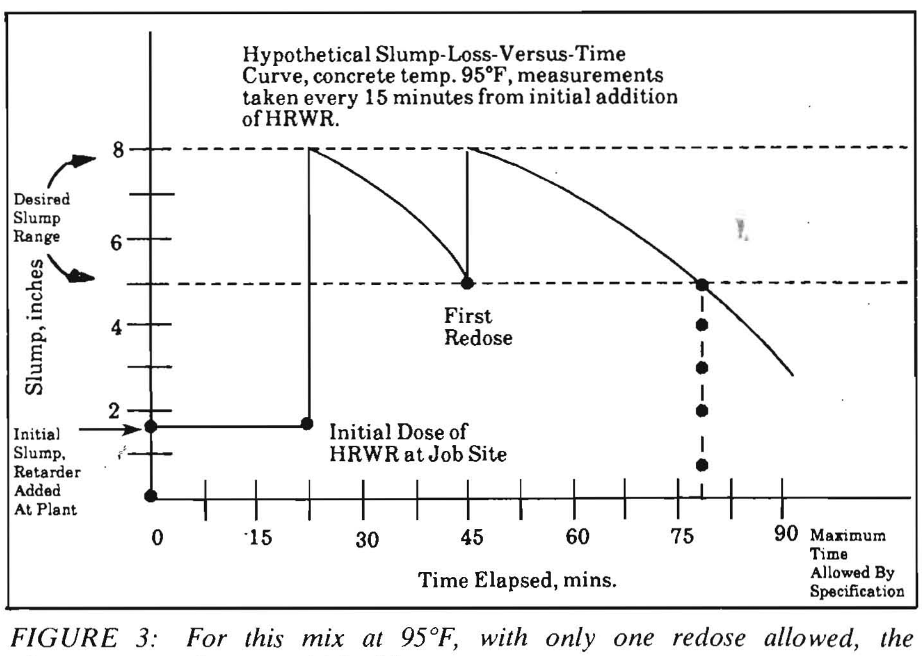

FIGURE 3: For this mix at 95°F, with only one redose allowed, the placement time limit would be 80 minutes.

er also capable of operating at an agitating speed.

3. *Batch design and equipment.* A copy of the batch design should be included. Construction form 309 may be used to show all the pertinent information. Proposed procedure suggests that the contractor/supplier prepare and test at least one full-sized batch using the equipment and batch design to be used on the job. To ensure adequate mixing, recommend the batch should be no more than 75 percent of the mixer capacity. SDHPT personnel should witness all tests, preferably with the project inspection team.

4. *Batching sequence.* Any admixtures to be added at the plant and their dosages, and HRWR dosage rate and addition method should be included in the work plan. When recommending the HRWR addition rate and method, the slump range in which the admixture will be added must also be identified.

5. *Slump-loss-versus-time curve and temperature-versus-time curve.* Include in the work plan

I. **General Data**

A. Project No., Control No., & County ____________

B. Structure Name(s) ____________

C. Structural Element(s) ____________

D. Contractor ____________

E. Concrete Supplier ____________

F. Cement Type and Brand ____________

G. Course Agg. Source and Grade ____________

H. Fine Agg. Source ____________

I. Admixtures (Brand Name) & Recommended Dosage Range

1. Air ____________
2. Retarder ____________
3. Water Reducer ____________
4. High Range WR ____________

J. Narrative on recommended charging sequence and mixing times at plant and job site, maximum batch size, dosage rates, maximum and desired slump, special procedures to control segregation.

K. If pumping is proposed, the slump before and after pumping and the air content before and after pumping should be considered and documented.

L. If multiple dosing with *HRWR* is allowed at site, this procedure should be modeled and tested on the full volume trial batch with appropriate air and slump testing, including air and slump loss with time. The re-dose dosage rate must be specified and included in the narrative.

M. Include a graph showing the slump loss vs. time and concrete temperature.

FIGURE 4: Outline for mix design using HRWR.

II. MIX DESIGN USING **HRWR** (continued)

BASE MIX		TRIAL ____#	TRIAL ____#	TRIAL ____#	TRIAL ____#
A. Course Aggregate	______lbs.	______	______	______	______
B. Fine Aggregate	______lbs.	______	______	______	______
C. Cement	______lbs.	______	______	______	______
D. Water	______lbs.	______	______	______	______
E. Admixtures					
1. Air	______oz.	______	______	______	______
2. Retarder	______oz.	______	______	______	______
3. Water Reducer	______oz.	______	______	______	______
4. High Range WR	______oz.	______	______	______	______
F. Cement Factor	______sacks/yards	______	______	______	______
G. Workability Factor	______	______	______	______	______
H. Cement Water Ratio	______gal/sack	______	______	______	______
I. Slump (initial)	______in.	______	______	______	______
J. Air Content	______%	______	______	______	______
K. Concrete Temperature	______F	______	______	______	______
L. Air Temperature	______F	______	______	______	______
M. Strength					
1. 7 Day Beam	______psi	______	______	______	______
2. 28 Day Cylinder	______psi	______	______	______	______
N. Slump Loss					
1. Initial + 15 min.	______in.	______	______	______	______
2. Initial + 30 min.	______in.	______	______	______	______
3. Initial + 45 min.	______in.	______	______	______	______
O. Time to Set	______hrs.	______	______	______	______
P. Air Content I + 30 min.	______%	______	______	______	______

FIGURE 5: Mix design using HRWR continued.

that the concrete used to develop these curves be batched under the most critical temperature conditions anticipated (Fig. 3). In order to have a meaningful curve, the slump and temperature should be taken every 15 minutes. The slump-loss-versus-time curve will be used to establish placement time limits for the anticipated maximum concrete temperature. Establishing placement time limits for a mix at a given temperature helps to eliminate any placement, consolidation, and finishing problems which may arise from the use of HRWR. Data provided on the curve will indicate the range of temperatures (the maximum temperature down to 60°) and maximum placement time that the specific concrete can be handled adequately in the field.

6. *Temperature control.* The maximum acceptable concrete temperature must be given in the work plan. It must be based on standard specifications or slump-loss-versus-time at the maximum anticipated temperature curve, whichever is lower. In trial batches, if one batch exceeds the anticipated maximum temperature, run a time-versus-temperature curve for that temperature and document the concrete's behavior. If the concrete does not show unusually rapid slump loss or finishing difficulties, it may be possible to use the newly established curve as the maximum temperature.

7. *Concrete strength.* Compressive or flexural strength, depending on job requirements, should be performed on the concrete being used to develop the slump-loss-versus-time and temperature-versus-time curves.

8. *Mixing time.* The mixing time/mixing revolutions prior to and after the addition of HRWR must be specified.

9. *Redose.* Any conditions that may require a redose of HRWR, if allowed, should be indicated. Also include the redose dosage, permissible slump range, and the mixing time after redose.

10. *Air content.* Air content, if required, should be taken before and after the addition of HRWR. If redoses are allowed, it should also be checked after the redoses.

11. *Contractor's preconstruction responsibilities.* Specify that the contractor is to plan, hold, and document a special preconstruction and training conference to discuss the results of testing, the proposed mix design, the anticipated site conditions, and potential problems. SDHPT project personnel responsible for material control are to participate.

SUMMARY

High-range water-reducers (HRWR), also known as superplasticizers, are chemical admixtures that can reduce water content in concrete mixes by up to 30 percent. They are used in the production of high strength (greater than 6000 psi) concrete of normal workability, high slump concrete of normal strength and high workability, and high strength, high slump concrete. They act by dispersing individual cement particles throughout the paste suspension. Analysis of hardened concrete made with superplasticizer often shows finer particles and denser structure within the cement paste.

If properly proportioned and placed, concrete made with a HRWR is of good durability and low permeability. However, there are problems associated with the use of HRWR; careful consideration of the intended application and job site must be made and, like any admixture, HRWR must not be used in place of good concreting practice. The problems of either segregation and bleeding or sticky, difficult finishing can be overcome by carefully adjusting the HRWR dosage and by carefully proportioning the mix (particularly selecting an optimum fines content). Other problems can be dealt with by following guidelines and by developing a practical work plan. The approved work plan, like a plan note, should supersede SDHPT highway specifications. Suggested guidelines and ideas for developing such a work plan have been outlined in this article. For more information, contact Mr. Gerald Lankes (D-9): TEX-AN 241-7331, (512) 465-7331; or Mr. Berry English (D-5): TEX-AN 245-5093, (512) 371-5093.

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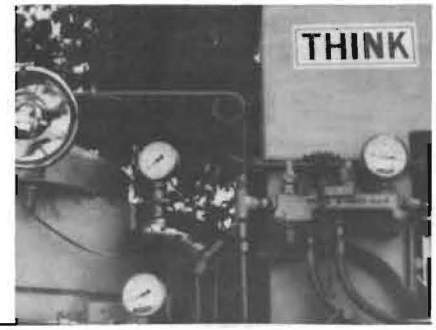
Good Advice Before Doing Anything...



PASSER II-87 MICROCOMPUTER PROGRAM SYSTEM

by Edmond C-P Chang, Ph.D., P.E.
Texas Transportation Institute
A&M University System

INTRODUCTION

PASSER II-87 is the acronym for Progression Analysis and Signal System Evaluation Routine. PASSER II was originally developed by the Texas Transportation Institute (TTI) for the Dallas Corridor Project. The Texas State Department of Highways and Public Transportation (SDHPT) has sponsored the subsequent development of PASSER II on both mainframe computers and microcomputers [1]. The theory, model structure, methodology, and logic of PASSER II-87 have been evaluated and documented. PASSER II has received widespread usage because of its ability to easily select multiple phase sequences by adjusting the background cycle length and progression speeds to find the optimal timing plans, such as cycle, green split, phase sequence, and offsets, that can efficiently maximize the two-way progression bands [2].

PASSER II-87 is the most recently enhanced version of the PASSER II program. PASSER II-87 microcomputer program Version 1.0 was completed under the Texas HP&R 2-18-86-467 study, ***Enhancements to PASSER II-84***, by the Texas Transportation Institute (TTI) of the Texas A&M University System. This new program was designed for ready use by traffic engineers and transportation professionals to optimize or to evaluate the isolated signalized intersection or coordinated arterial street system of up to 20 signalized intersections.

PASSER II-87 is a powerful, easy-to-use, and user friendly signal-timing program for IBM PC/XT/AT/386 or compatible microcomputers having the PC DOS or MS DOS 2.1 or higher diskette operating systems (DOS). The program requires a microcomputer with a minimum of 512K RAM (Random Access Memory) and two double-sided double-density (DS DD) floppy drives, or one double-sided high-density (DS HD) floppy diskette drive. However, it is highly recommended that the program be used on hard disks for fast execution. The system will be distributed to SDHPT personnel with the main program, input preprocessor, output postprocessor, optional help information, and microcomputer user's manual for the PASSER II-87 microcomputer program system.

PASSER II-87 combines the updated version of PASSER II, advanced analysis procedures similar to those in the ***1985 Highway Capacity Manual***, and the latest microcomputer technology. There are three major applications: (1) isolated intersection timing evaluations, (2) progression signal timing optimization, and (3) "Existing Timing Evaluation" or "Simulation Evaluation." The program assumes the isolated evaluation as the default if the input data pertain to only one intersection. On the other hand, this program assumes progression if the input data include more than one intersection in the system. In progression, PASSER II-87 seeks to maximize two-way bands and minimize signal delay based on the combination of traffic volumes, saturation flows, and minimum phase times under a given cycle length range. To analyze an isolated intersection, traffic turning movements and intersection approach saturation flow rates are needed. Minimum phase times for each movement must also be provided. PASSER II-87 can optimize the signal phasings ranging from the simplest two-phase operations to the most complex, variable sequence, multiphase coordination. The signal phasing is described on a "permitted" or "allowed movement" basis. Up to four possible arterial phasings are permitted at any one intersection, whereas each cross street can have only one of four possible phase sequences. In addition to the normal protected or permitted left turn phasing, it can further analyze the complicated permitted/protected or protected/permitted "combined phase" left turn sequences. The system employs the most advanced highway capacity technology. Therefore, PASSER II-87 may also be used as a traffic planning or capacity analysis tool if volumes, saturation flows, intersection geometrics and signal timing are known [3].

PROGRAM FEATURES

PASSER II-87 has a complete stand-alone microcomputer user interface for the interactive arterial progression and intersection capacity analysis [1]. It is an engineering tool that can be used to produce minimal delay and good arterial progression. TTI and SDHPT have designed the microcomputer input/output system so that an engineer who is not too familiar with a microcomputer can still effectively start the system to solve signal timing and evaluation problems. The input/output process helps users through the interactive query with data input guidelines and sets of help menus in the data input process. Routine data coding checks will help the users to modify the data without having to exit the PASSER II-87 system. After all the input has been completed, the system examines the input data, automatically stores it in a data file, executes the program, and then allows the user to review or to print out specific output as needed.

PASSER II-87 (Fig. 1) comprises the most advanced microcomputer technology with an intelligent, user-friendly menu interface in the input/output proces-

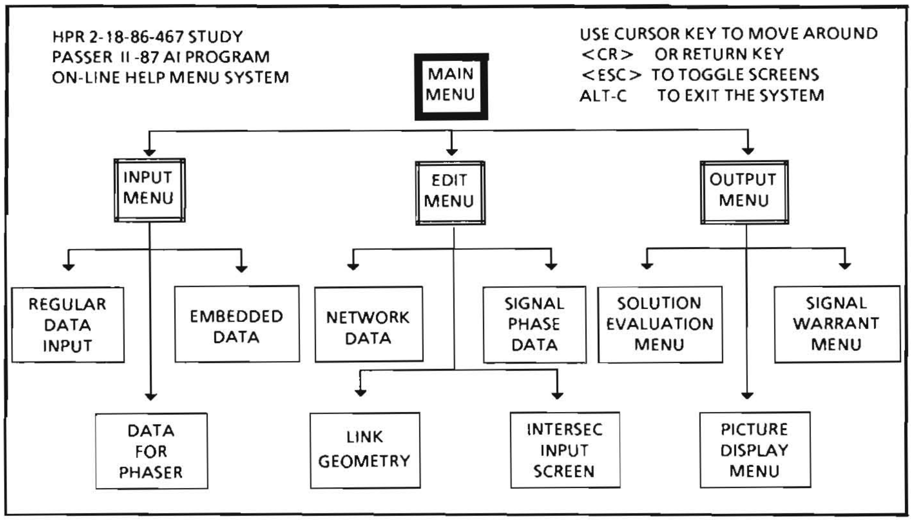


FIGURE 1: PASSER II-87 Microcomputer system menu structure.

sor. The system was developed so that it would accept all the existing PASSER II or PASSER II-84 data without requiring any manual user modification. The data can be entered or modified through either the full-screen, cursor keyboard, or mouse interface. The operator can exit the current state at any time by pressing the "escape" key. The built-in help windows are provided by pressing the FUNCTION KEY [F1] OR [F2]. In addition, users can even tailor the content of the global help screen according to their own agency-specific requirements through the use of the global PASSER II-87 help menu by using the FUNCTION KEY [F6]. Two other utility functions, like those available in many commercial packages, are also provided in PASSER II-87 to assist users in providing efficient traffic analysis. The FILE DIRECTORY function can be reached at any time by pressing the FUNCTION KEY [F4] for reviewing and providing the needed file management. More importantly, the EXTERNAL DOS SHELL function can be activated by pressing the FUNCTION KEY [F5] to allow users to reach the Diskette Operating System (DOS) command line interface level. The user can perform all the file maintenance functions, such as formatting new diskettes, backing up files, and performing other analyses, without even having to exit from the PASSER II-87 system.

PASSER II-87 provides an exceptional list of output features. The output is headed by an echo of arterial parameters (COVER), a listing of system embedded data (EMBED.DATA), an intersection input (INPUT.DATA), and an error report (ERROR.MSG). The optimized solution output provides a listing of the optimal timings for the arterial street (ART.SUMY), optimal signal timing plans for each intersection (INT.SUMY), a series of level-of-service evaluations for each phase (BEST.SOLN), total arterial system performance (ART.MOE), signal controller phase interval setting report (PIN.SET), and the optimal time-space diagram (TS.DIAGM), if requested. The implementation of the optimal timing plans can be greatly facilitated through the use of phase interval tables with respect to the system master intersection for the microprocessor-based, traffic-actuated signal equipment (Fig.2) [3].

PROGRAM IMPLEMENTATION

The program permits the engineers to interact with the overall analysis process while relieving them from the tedious and repetitive manual calculations. Several program runs and some engineering judgment in the selection of proper input parameters may be needed before the final signal timing solutions can be produced. In response to the user desire to modify the embedded input data used in analysis, new features have also been added to let users adjust

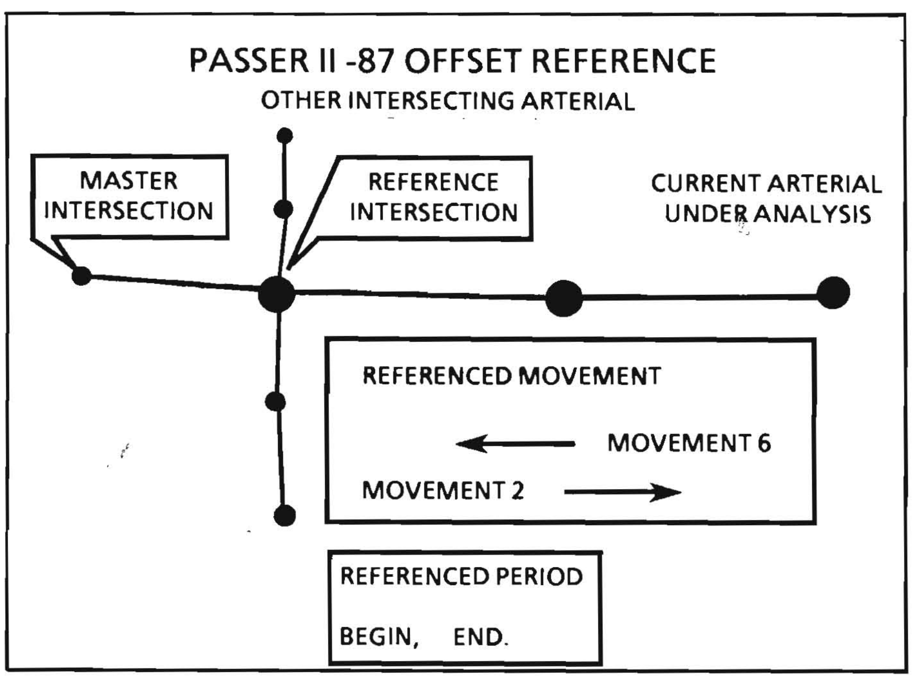


FIGURE 2: PASSER II-87 offset reference.

PASSER II-87 EMBEDDED DATA INPUT SCREEN

Pretimed or Actuated (P or A) = P	Sneakers, S = 2.0
Ideal Saturation Flow = 1800 pcphgpl	Phase Lost Time, L = 4.0
Analysis Period, T = 15 minutes	Left Turn P+P(A or R) = A

LOS Delay Criteria : Total Delay, Multiplier M = 1.3

A : 5 * M = 6.5	C : 25 * M = 32.5	E : 60 * M = 78.0
B : 15 * M = 19.5	D : 40 * M = 52.0	F > 60 * M = 78.0

Model Form : Negative Exponential

> Texas A&M	Analytical Model <
Australian	Analytical Model
Univ. of Texas	Simulation Model
Your Own Model	Same Model Form

VO	- Opp Sat Flow	(vph)	1750
T	- LT Critical Gap	(sec)	4.5
H	- LT Headway	(sec)	2.5

SL = Exponential Function of (VO, T, H)

"P" for Pretimed or "A" for Actuated

FIGURE 3: PASSER II-87 embedded data screen.

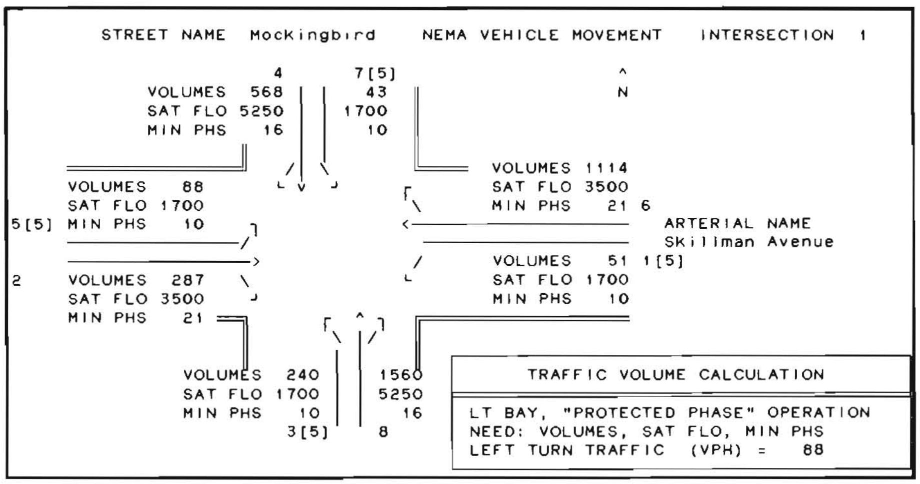


FIGURE 4: PASSER II-87 movement data screen.

all the embedded data in PASSER II, if needed. The default data (Fig. 3) have been prepared. These embedded data include the traffic control type, ideal saturation flow rate, analysis period, number of left turn sneakers, individual phase lost time, combined left turn phase reference, delay level-of-service evaluation, total delay adjustment factor, basic HCM delay criteria, permitted left turn models, and the recommended left turn model coefficients. Another new feature in PASSER II-87 is the addition of the data input "ASSISTANT" function for assisting users to input the traffic-movement-related information graphically, such as the turning traffic movement volume (VOLUME), saturation flow rate (SAT FLO), and the minimum phase time (MIN PHS). The program's "ASSISTANT" allows users to analyze the movement-based information freely, following the analysis procedures similiar to the ***1985 Highway Capacity Manual*** (HCM) (Fig. 4).

LEFT TURN SIGNAL TREATMENTS

Due to the need for assisting users in analyzing different left turn signal treatments under coordinated progression analysis, PASSER II-87 has been significantly enhanced. These improvements include the data input procedure, input data structure, green split calculations, progression calculations, and program output evaluations. PASSER II-87 left turn input uses the minimum amount of input information to generate the possible left turn treatments as well as the allowable signal phase sequences. The input data was designed to simplify the user's input for analyzing the various possible left turn signal treatments. First, the program will ask the user to provide the needed information concerning the use of the protected left turn bay for the corresponding left turn traffic movements. Then, the program will automatically generate the appropriate treatments according to the user's input for the different left turn and through traffic movements. The intelligence implemented in the PASSER II-87 program will allow the user to determine the proper types of left turn signal treatments from their input. The system will inquire and infer from the conditions in the following steps:

1. Use traffic volume to distinguish the use of left turn bay;
2. Use minimum phase time to indicate the use of protected left turn phases;
3. Ask "Is left turn protected only?" for the combined phase operation; and
4. Use the phase sequence to select "which" combined phase.

SYSTEM SUMMARY

The PASSER II-87 Microcomputer Environment System was developed by TTI for the Texas SDHPT to facilitate signal design and evaluation. The system was developed for use on the IBM PC/XT/AT/386 or compatible microcomputer. The new system has many advantages over the existing PASSER II-84 program being distributed [2]. It provides a very user-friendly menu interface, full-screen cursor movements, and accepts all the existing coded PASSER II-84 data without requiring user modification. If desired, the user can freely modify any embedded data for analysis, and the system will faithfully report all the data used. PASSER II-87 has been enhanced tremendously to provide the graphical traffic input and the "ASSISTANT" function to help users with the 1985 HCM capacity analysis. The system can analyze all the commonly available left turn signal treatments, either with or without protected left turn phases or protected left turn bays. The system can also investigate the operational effects of the "combined phase," i.e., "protected plus permitted" or the "permitted plus protected" left turn signal phasings. The new system provides an improved scheme for allowing the input of the existing or user-selected offsets for arterial capacity evaluation. The system will provide the user with the im-

Continued on page...16

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"Hot Mix & Concrete Construction Inspection," Dec. 11-16

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proved user-specified controller Phase Interval Setting (PIN.SET) report and an enhanced optimal Time-Space diagram (TSDIAGM).

A "Microcomputer User's Guide" has been written to be distributed with the program package. It was developed for those users who are already familiar with the PASSER II program and desire to use the PASSER II-87 microcomputer program to analyze arterial signal system design problems [3]. Any questions concerning how the PASSER II program operates or what type of data input it needs will be best answered in the "PASSER II User's Manual." Please address all written correspondence or requests to the State Department of Highways and Public Transportation, File D-18STO (PASSER II-87), 11th and Brazos Streets, Austin, Texas 78701-2483, (512) 465-8353 or TEX-AN 258-8353.

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