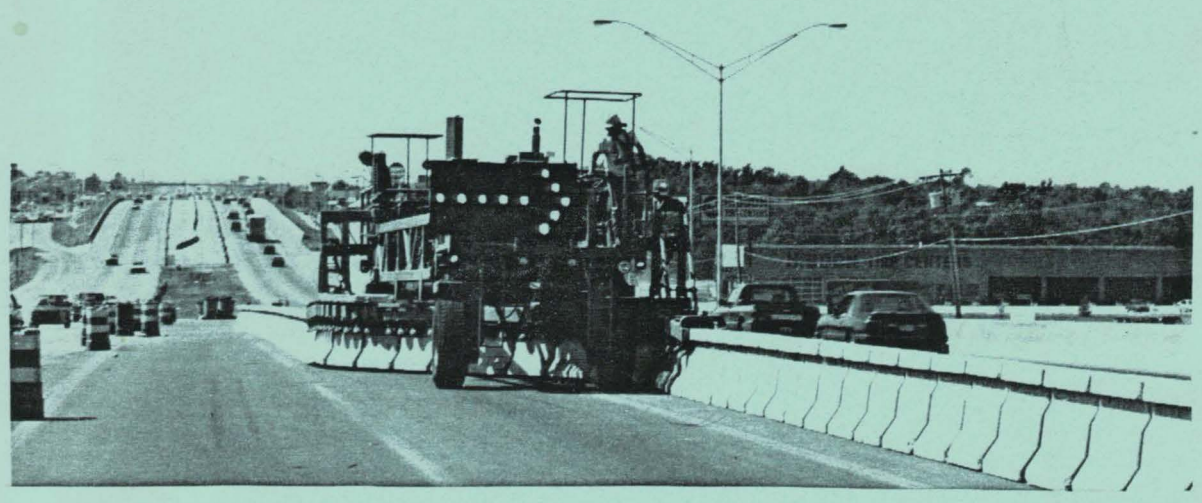
QUICKCHANGE MOVEABLE CONCRETE BARRIER SYSTEM



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Research Project Manager

FINAL REPORT

Under the Supervision
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July, 1992

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16. ABSTRACT

Highway construction operations must often be carried out in locations adjacent to active traffic lanes. When this happens, both workers and motorists are exposed to greater hazard levels than would be the case on a "closed roadway" worksite.

Project IR-240-4(324)000 included a situation where contract requirements specified that lane closures could take place only between 7:00 PM and 7:00 AM. Both traffic conditions and the nature of the work on this project indicated a need for a barrier system between construction operations and motorists. A Quickchange Moveable Concrete Barrier (QMCB) System was purchased to meet the requirements of this project. The QMCB Systen was evaluated by the Oklahoma Department of Transportation (ODOT) Research and Development Division.

During Project IR-240-4(324)000 14,600 L.F. of QMCB Barrier was produced by a subcontractor and used on this project. 88 separate QMCB barrier wall shifts were made during work on the project. A total of 393,101 L.F. of QCMB barrier was shifted. Information regarding barrier wall shifts was obtained by monitoring shifts, and by interviewing ODOT Construction personnel and contractor's employees.

During the study, numerous collisions involving the QMCB Wall occurred. Only 12 of these accidents were reported to authorities. Accident Reports were requested from the Oklahoma Department of Public Safety. Selected items of information from these reports were analyzed.

Performance of the QMCB System on this project was considered to be positive, both from an operations standpoint, and regarding its effectiveness as a protective barrier.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

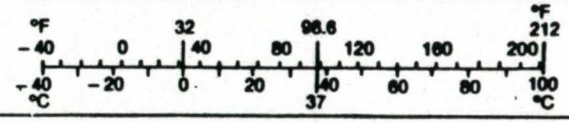
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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Table of Contents

List of Illustrations

List of Tables

INTRODUCTION

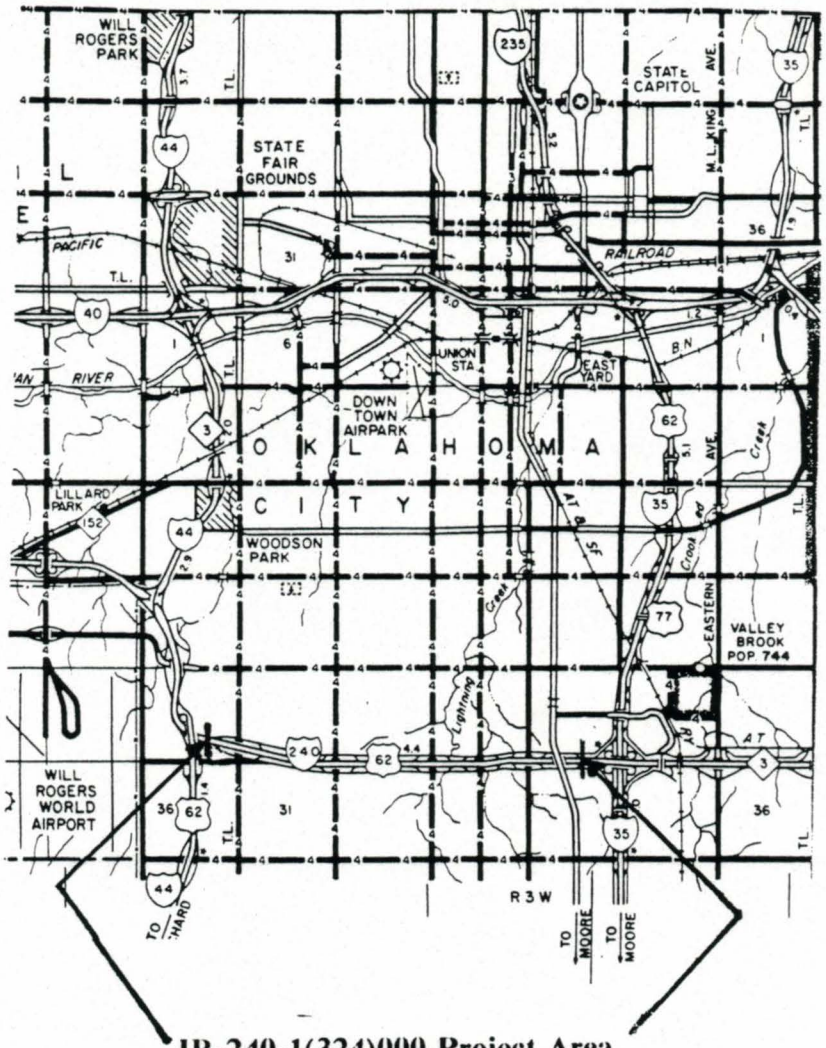
In recent years, the nation's highway program has shifted its emphasis from new highway construction to repair and renovation of existing facilities. This shift is causing a greater proportion of work to be done under conditions that require barrier walls separating active traffic lanes and work areas.

The Oklahoma Department of Transportation (ODOT) has completed Project IR-240-1(324)000, a four mile long reconstruction project on I-240 in Oklahoma City (Figure 1.) The project was located in an area where several shopping centers and businesses adjoined I-240. This section of I-240 carries an ADT of approximately 70,000, which includes large numbers of commuters.

To minimize the effects of construction on the businesses and commuters, it was decided that construction operations involving lane closures would be done at night. Lane closures were allowed only after 7:00 P.M., and closed lanes were required to be reopened before 7:00 A.M. The nature of the work on this project (bridge widening and adding traffic lanes) caused much of the work to be done in close proximity to active traffic lanes. A barrier system was required for the protection of both contractor's employees and motorists. Lane closure requirements dictated that the system be moveable. Reports from other agencies indicated that the Quickchange Moveable Concrete Barrier (QMCB) was capable of handling Project IR-240-1(324)000 requirements. A QMCB System was purchased from Barrier Systems, Inc., Sausalito, California.

Critical Path Scheduling has been in use since the project began. The contractor, Nielsons, Inc., has submitted weekly updates of work schedules to ODOT since the first barrier shift took place on this project. Each update has included planned work activities for the following four weeks. In addition to providing dates when barrier moves would be made, this allowed ODOT to make public service announcements, and notify local police and fire officials when temporary closures of streets crossing I-240 were necessary due to work on overpasses.

The length of barrier involved in each move was 2,500 to 5,000 L.F., with two moves required to close, then reopen, a lane. Moving this amount of New Jersey Barrier, by conventional means, would have been difficult, and very time consuming.



IR-240-1(324)000 Project Area.

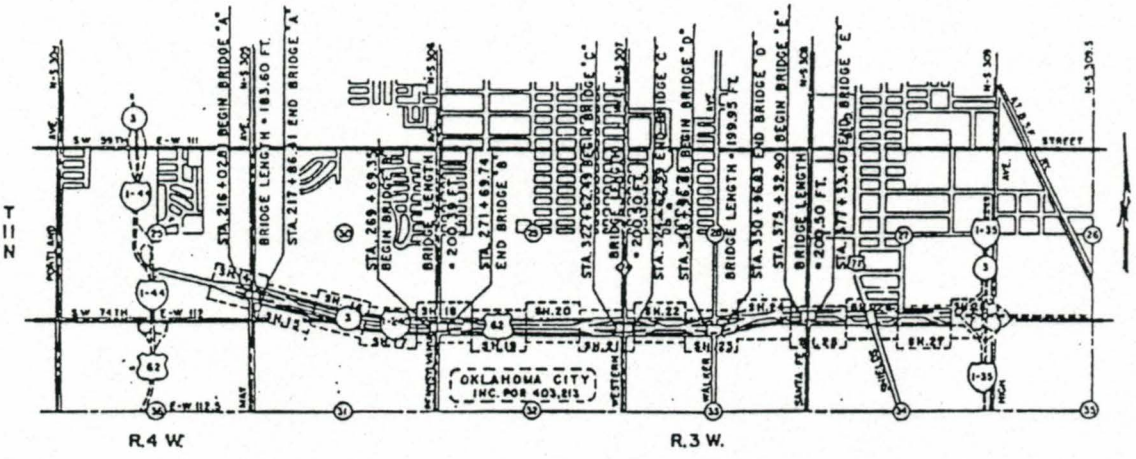


Figure 1. IR-240-1(324)000 Project Location.

QUICKCHANGE MOVEABLE CONCRETE BARRIER (QMCB) SYSTEM

Barrier Walls

The barrier wall of the QMCB System consists of a "chain" of 3.28 foot (one meter) long reinforced concrete barrier segments. The cross section of each segment is similar to that of New Jersey Barrier with a flange on both sides at the top of the segment (Figures 2 and 3). Rubber pads are attached to the bottom of each segment to minimize the possibly of "creep". Four 7/8 inch diameter steel rods run the length of each segment and are attached to hinges at either end (1,2). Each segment weighs roughly 1,400 pounds.

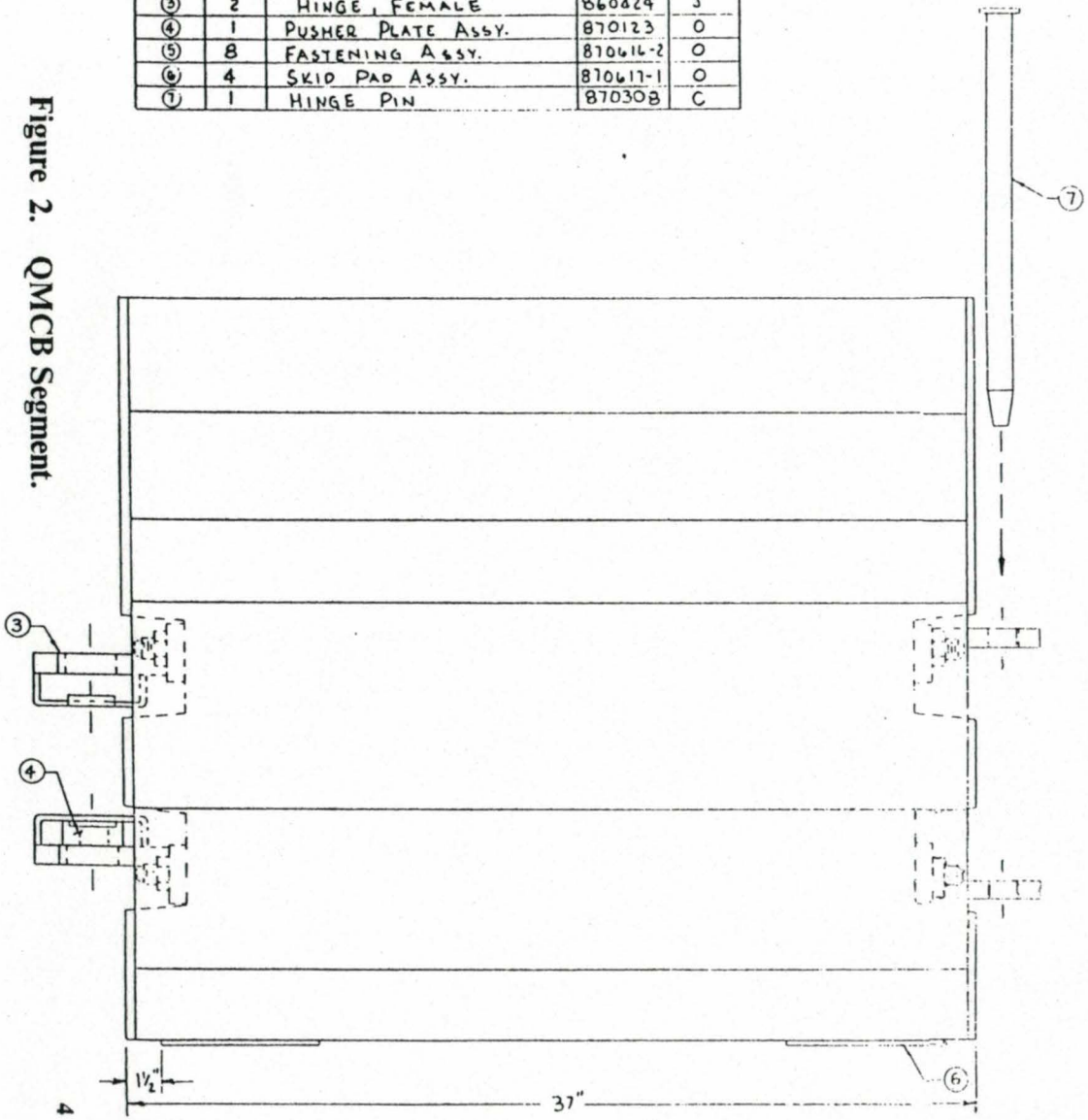
Any number of segments may be pinned together at the hinges to form a continuous concrete barrier wall of the length desired for a particular task. The "T" shaped flange at the top of each segment allows it to be picked up, and moved by the Transfer and Transport Vehicle (TTV), as described in the following paragraph. ODOT Special Provisions covering QMCB wall are included in Appendix A.

Transfer and Transport Vehicle (TTV), Operation and Capabilities.

To shift the QMCB Barrier wall, the operator drives the TTV into position such that the carrier wheels are located on each side of the "T" shaped flange on the segments (Figure 2). Then, as the TTV moves forward, the barrier wall segments are lifted by the incline on the the pickup mast, located on the front of the conveyor track (Figures 4 and 5). The TTV has identical controls on each end and can shift the barrier while travelling in either direction. Also, it has the capability of lifting barrier segments up to 30 inches vertically to accommodate curbs, adjacent structures, or other obstacles.

Lateral barrier wall shifts of 6 to 16 feet can be made in one pass. Use of the system is most feasible on Projects where lanes must be closed for work, then reopened within a relatively short time. Experience on this project indicates that TTV speeds of 3 to 5 mph are most effective during barrier shifts, although the TTV can shift barrier at higher speeds. The TTV has the capability of carrying up to 15 segments (roughly 50 L.F. of barrier wall), to place it where required on a project. ODOT Special Provisions covering the TTV are reproduced in Appendix A.

ITEM	QTY.	DESCRIPTION	DWG #.	REV.
①	1	BARRIER MODULE, CONST.	861222	O
②	2	HINGE, MALE	860425-1	F
③	2	HINGE, FEMALE	860424	J
④	1	PUSHER PLATE ASSY.	870123	O
⑤	8	FASTENING ASSY.	870616-2	O
⑥	4	SKID PAD ASSY.	870617-1	O
⑦	1	HINGE PIN	870308	C



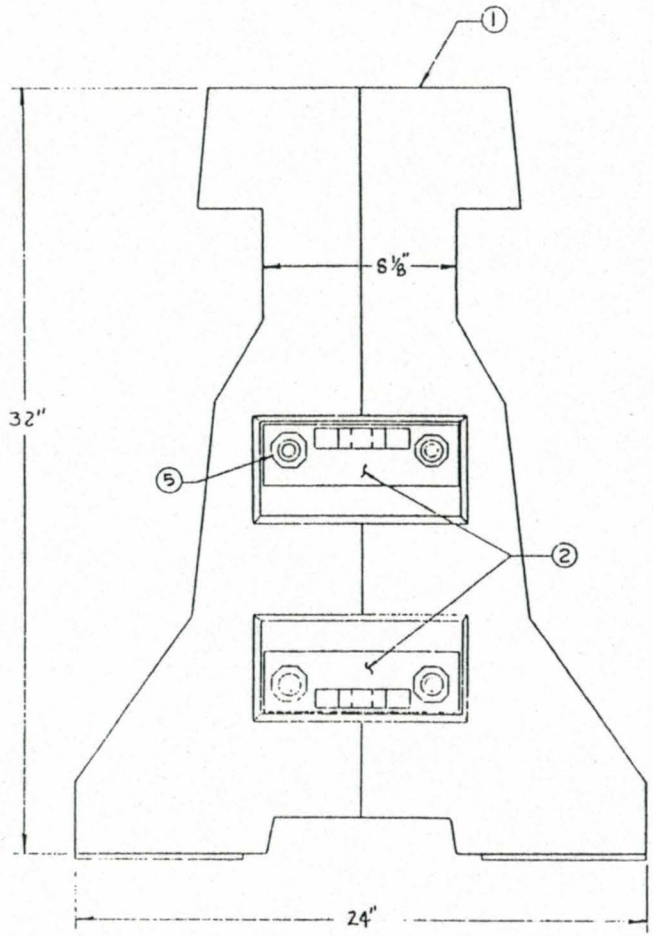
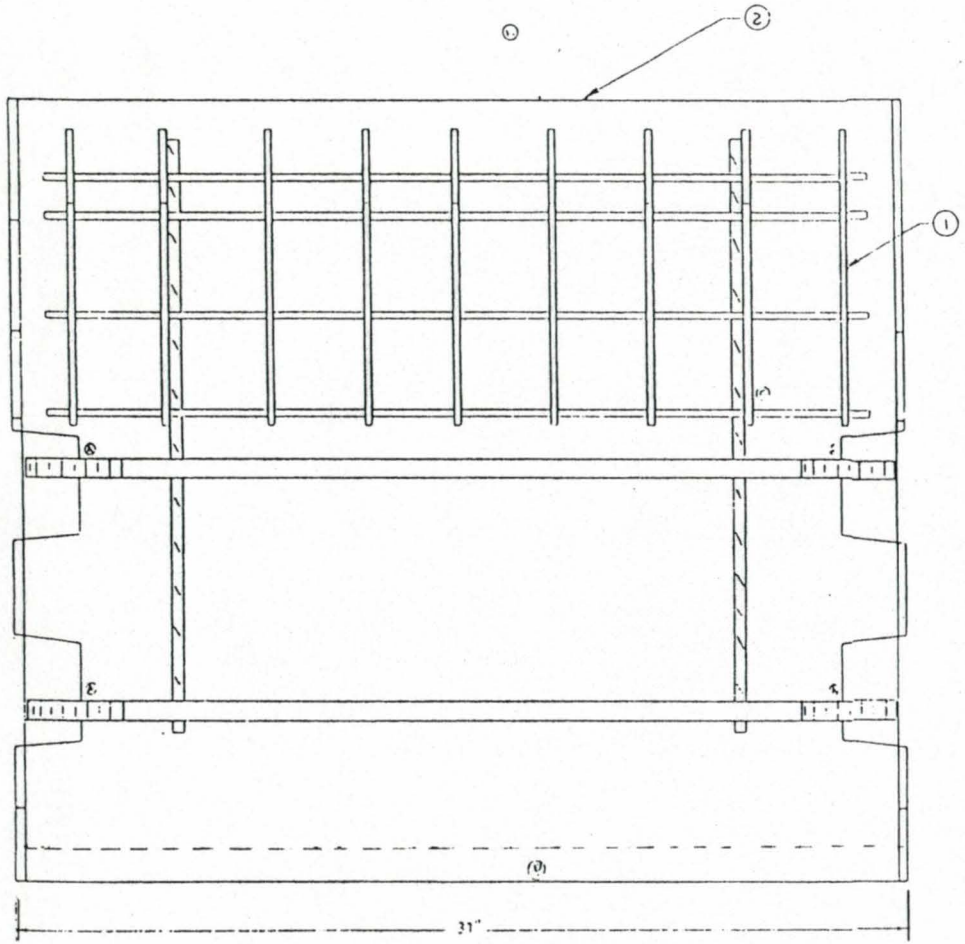
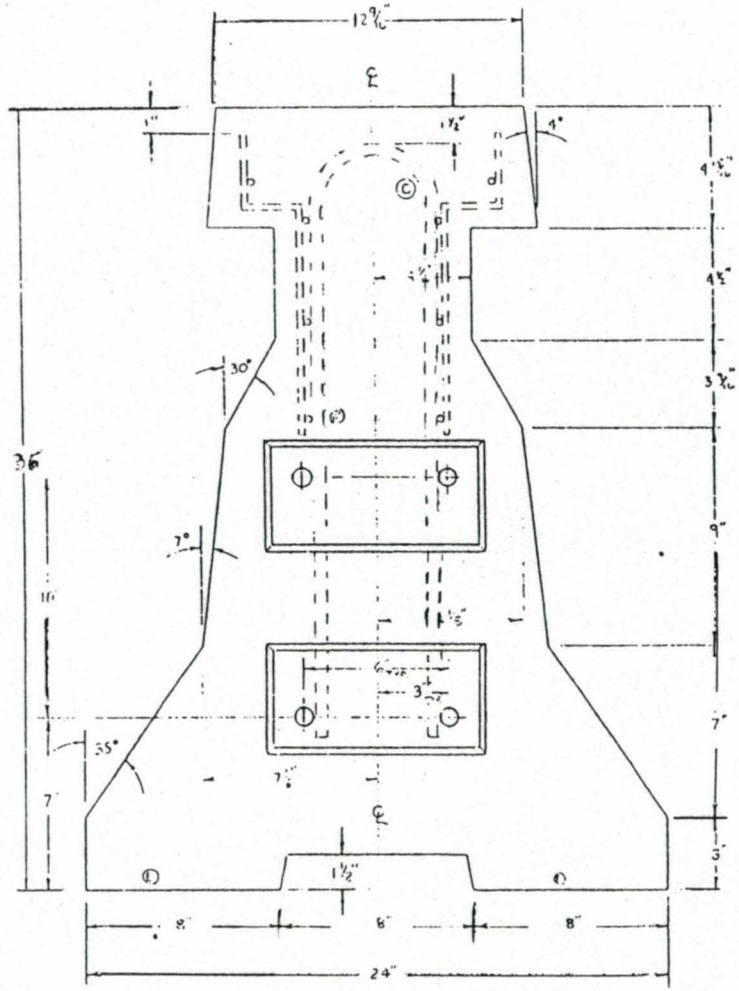


Figure 2. QMCB Segment.

BARRIER SYSTEMS INC.		
SCALE: ¼"-1"	APPROVED BY:	DRAWN BY A.C.
DATE:		REVISED
BARRIER, SERIES 200		
		DRAWING NUMBER 870616

A	3-3-87	REVISED PER ECN # [illegible]	[illegible]
B	3-12-87	REMOVED 1" BAR-E WAIR	KC
C	3-18-87	ROUND OF REVISIONS [illegible]	AC
D	5-26-87	[illegible]	KC
E	5-26-87	CHANGED 4" PAD DEPTH	AC
F	5-26-87	ADD STL ASSY. INSIDE HINGE LOOP	AC





ITEM	QTY	DESCRIPTION	DWG #	REV.
①	1	REINFORCEMENT ASSY.	B70209	D
②	1	CONCRETE CASTING	B70617	O

NOTE
ALL TOLERANCE = ¼" EXCEPT WHERE NOTED

BARRIER SYSTEMS INC.

SCALE: 1/10 = 1	APPROVED BY	DRAWN BY:
DATE: [illegible]		REVISED

BARRIER MODULE, CONSTRUCTION

CONST. BARRIER - SERIES 200 | DRAWING NUMBER B61222

Figure 3. QMCB Segment Reinforcement.

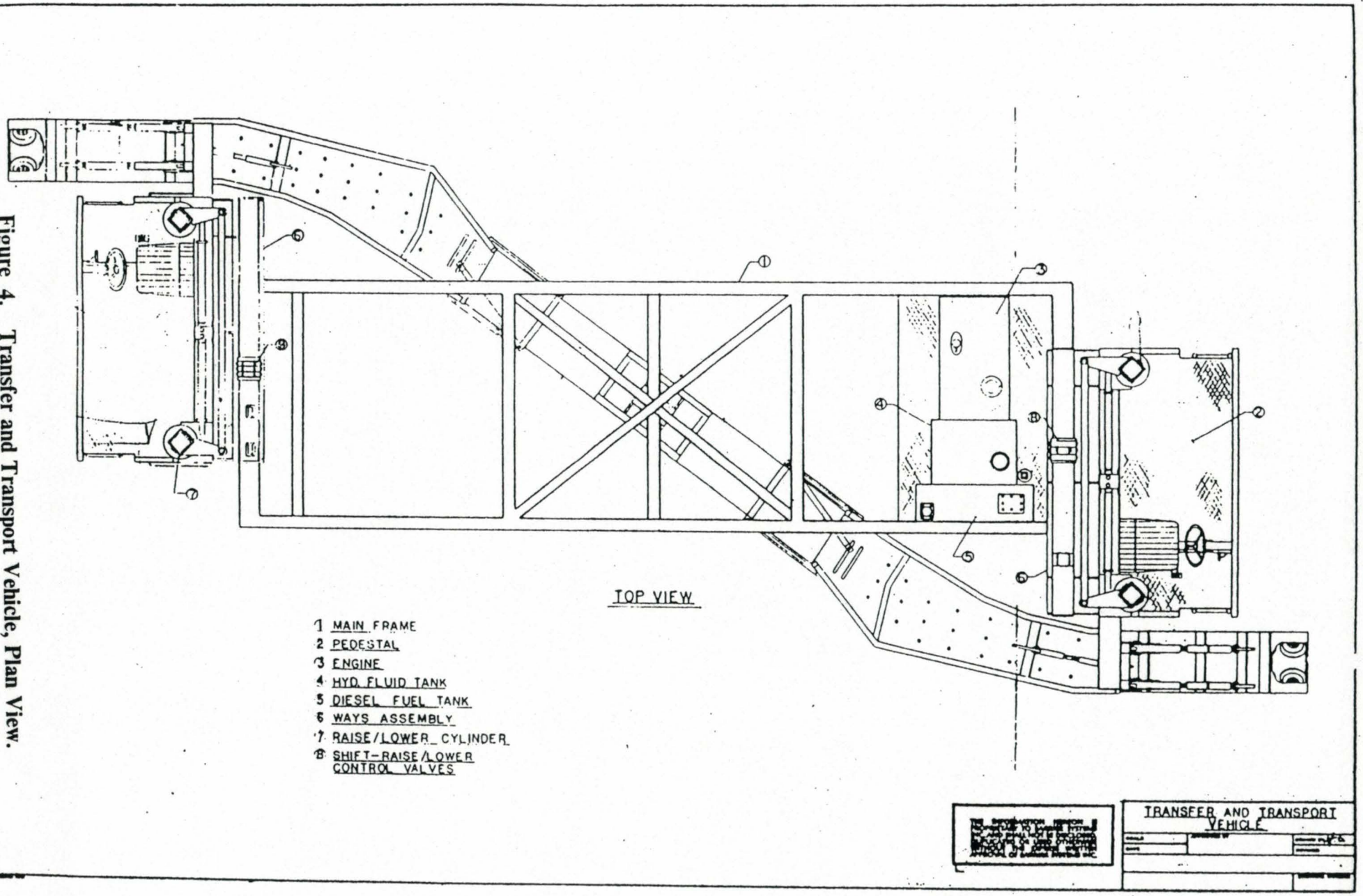


Figure 4. Transfer and Transport Vehicle, Plan View.

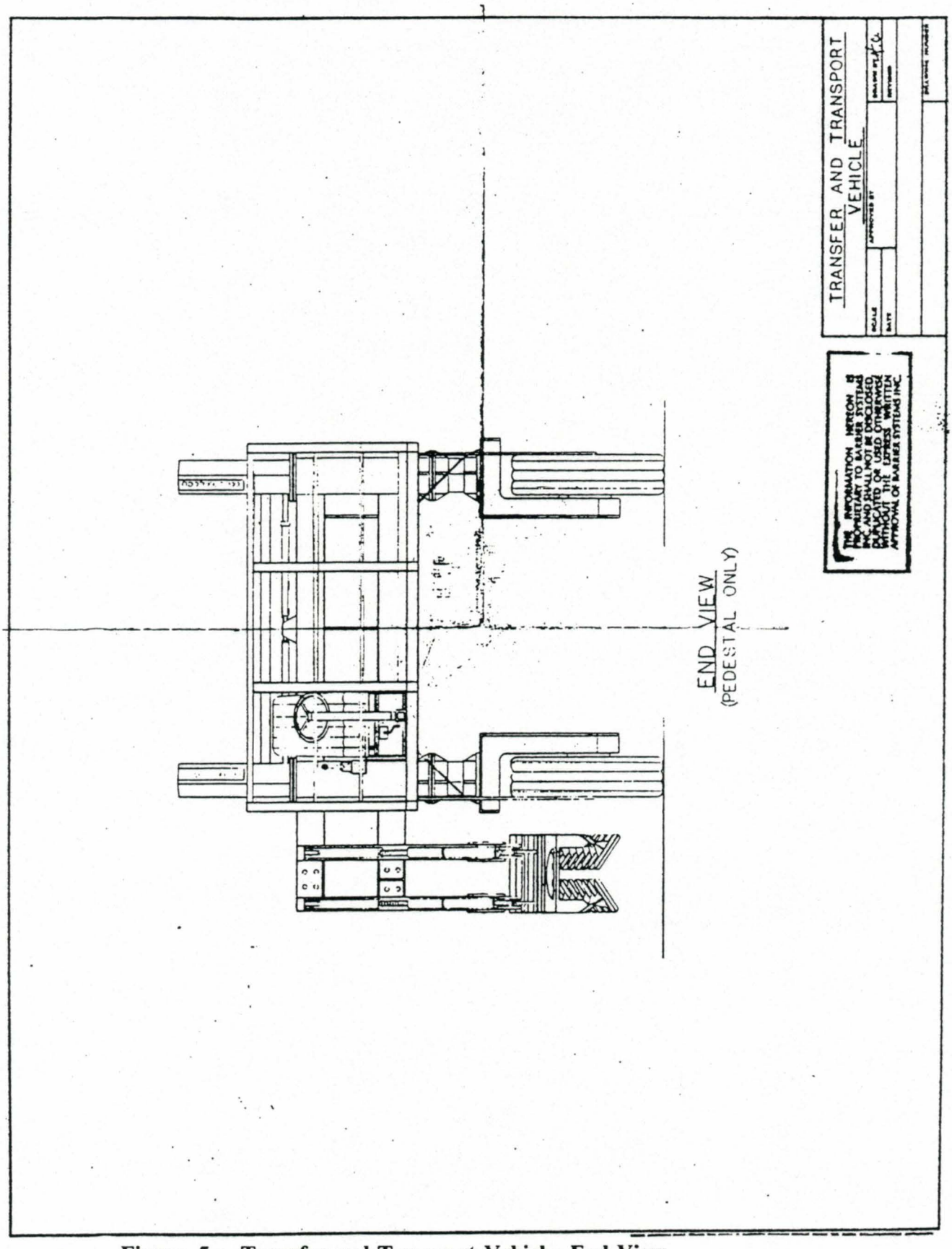


Figure 5. Transfer and Transport Vehicle, End View.

BARRIER SYSTEMS INC.

Production of Barrier Segments

Manufacturing of the barrier wall segments was subcontracted to American Precast, Inc. This firm has been producing ten (10) foot long New Jersey Barrier sections at their Marlow, Oklahoma plant for several years. Equipment at the the Marlow Plant was easily adaptable to QMCB segment pouring, due to the similarity of the two types of barriers. The major difference between pouring QMCB segments and New Jersey Barrier sections is the forms used. Barrier Systems, Inc. supplied QMCB forms to American Precast, so this was not a problem. Hinge units, bolts, plates, and pins were delivered in ready to use condition. Reinforcing steel is also received at the plant ready to be tied and put into the forms.

Because of American Precast's experience pouring N.J. Barriers, they were familiar with shifts required to pour daily, remove forms, and set up for the next pour. This may have been a factor in keeping up the production rate necessary to have segments ready and delivered in advance of project requirements.

Delivery and Original Setup of Barriers.

After QMCB segments are poured, and forms are stripped off, they are cured, linked together in four (4) segment lengths, and stacked (Figure 6). Stacking is done by a crane using a clamp designed to pick up barrier units (Figure 7). The clamp is available through Barrier Systems,Inc.

Barrier units stay in four (4) segment (13.12 feet or 4.0 meter) lengths from this point on. They are then loaded on flatbed trucks, and delivered to the project site. At the site they are placed in their initial configuration by a mobile crane, handling four (4) connected segments at a time. Any number of units are then connected to form the required length of barrier wall. As portions of a project are completed, segments that are no longer needed are removed in the same manner. Trucks take them to stockpile locations, and they are stacked by crane (Figure 8).

Barrier System Deployment on Project IR-240-1(324)000

This project consisted of rehabilitating approximately four (4) miles of I-240. The project included: Converting access roads on each side of I-240 from two-way to one-way streets, and providing exit ramp and access road traffic "turnaround" left turn lanes to access roads on the opposite side of I-240. Also, five (5) I-240 bridges were widened to accommodate the addition of two traffic lanes. The two (2) additional lanes were added to the entire project area.

QMCB walls were used to separate I-240 traffic from construction operations during work on bridges and in the median. Barrier wall configurations for these operations are shown in Figures 9 and 10.

Approximately 2,500 L.F. of barrier wall was deployed, on each side of the roadway, at each overpass bridge where I-240 crossed city streets.

When working space requirements made it necessary to temporarily close a driving lane, the QMCB wall was shifted in accordance with contract

requirements outlined earlier. During this project, a total of 393,101 L.F. of Barrier was shifted. This involved 88 separate shifts.

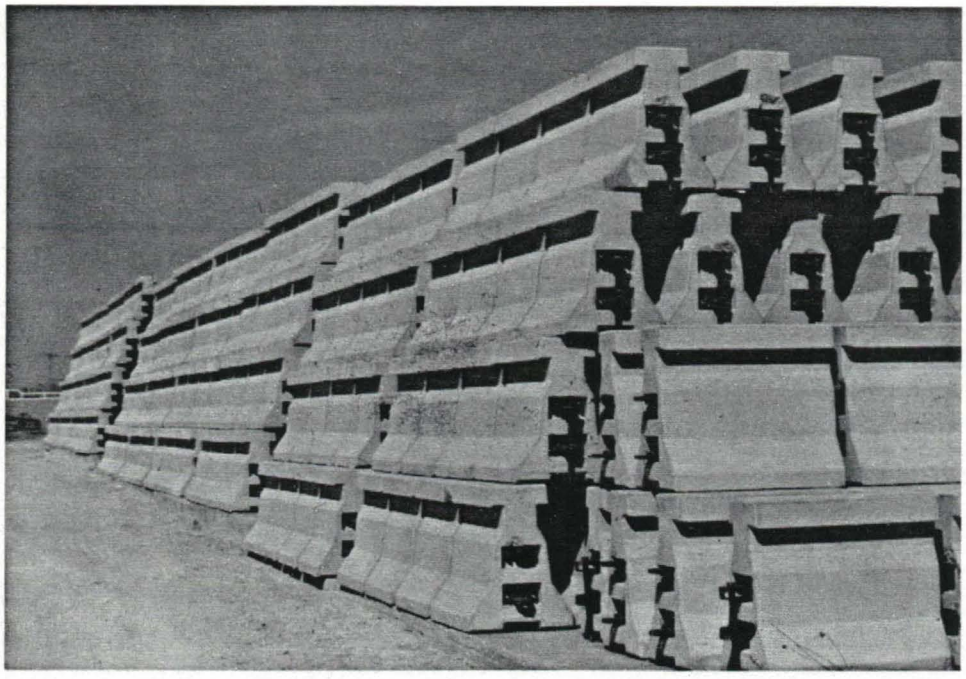


Figure 6. Stacked four (4) Segment Lengths of QMCB.

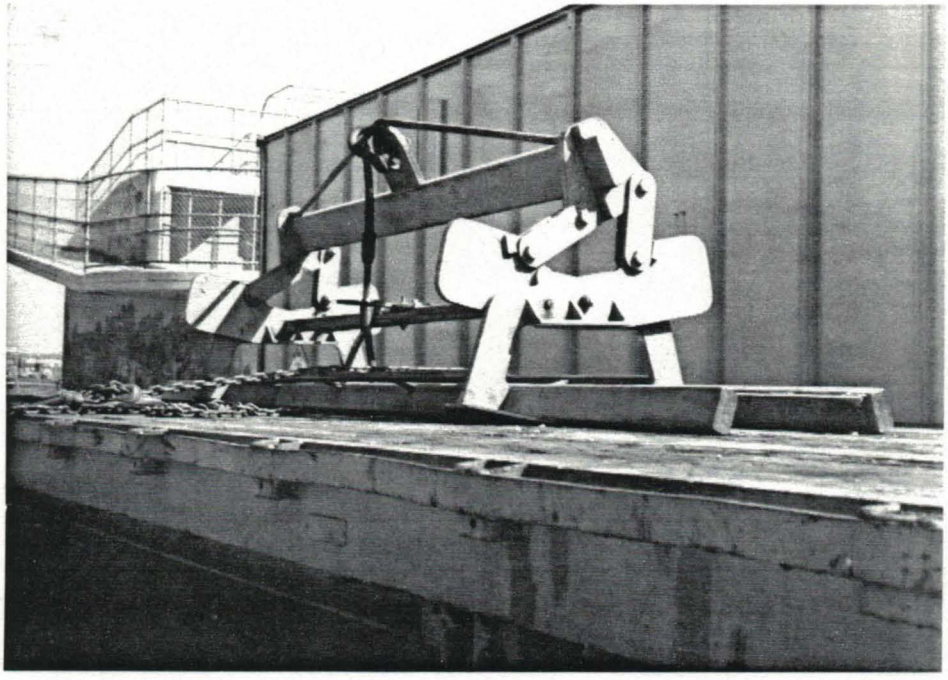


Figure 7. Clamp Used to Lift Barrier Segments.

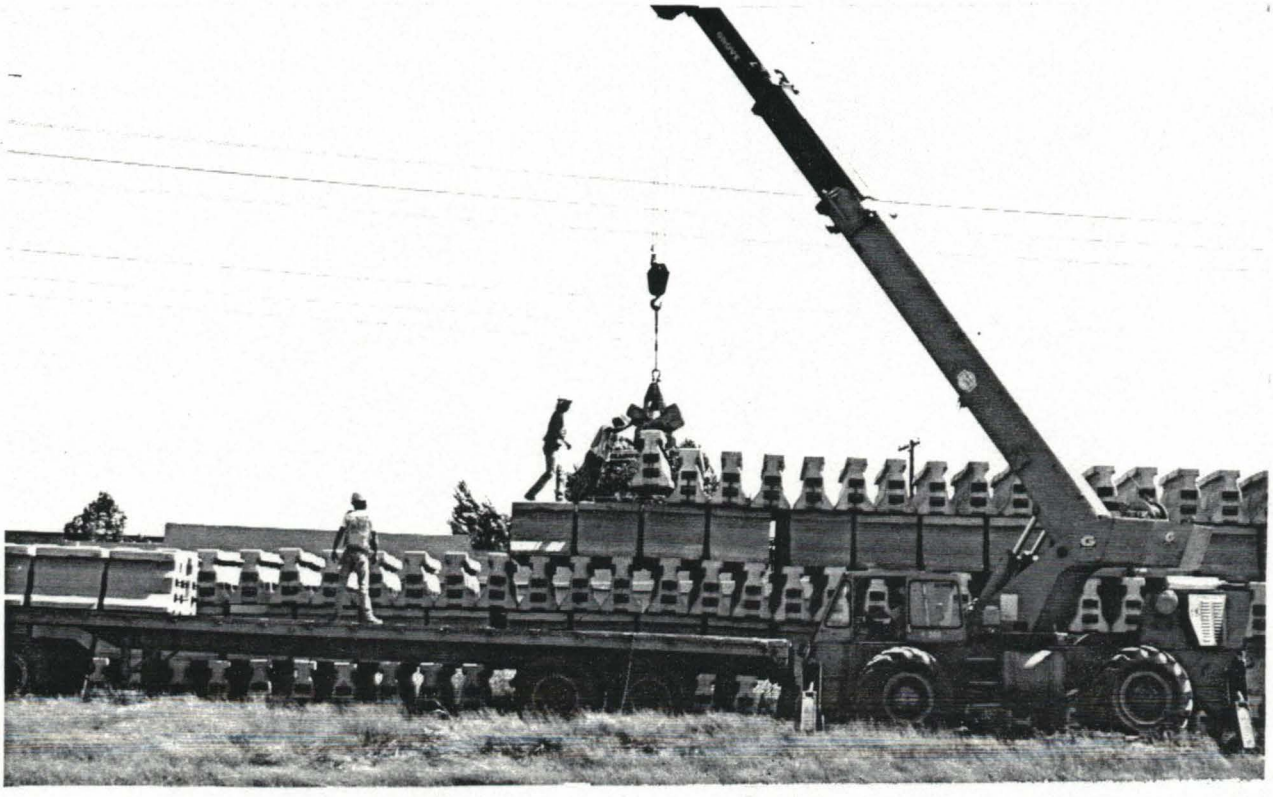


Figure 8. Stockpiling QMCB Segments.

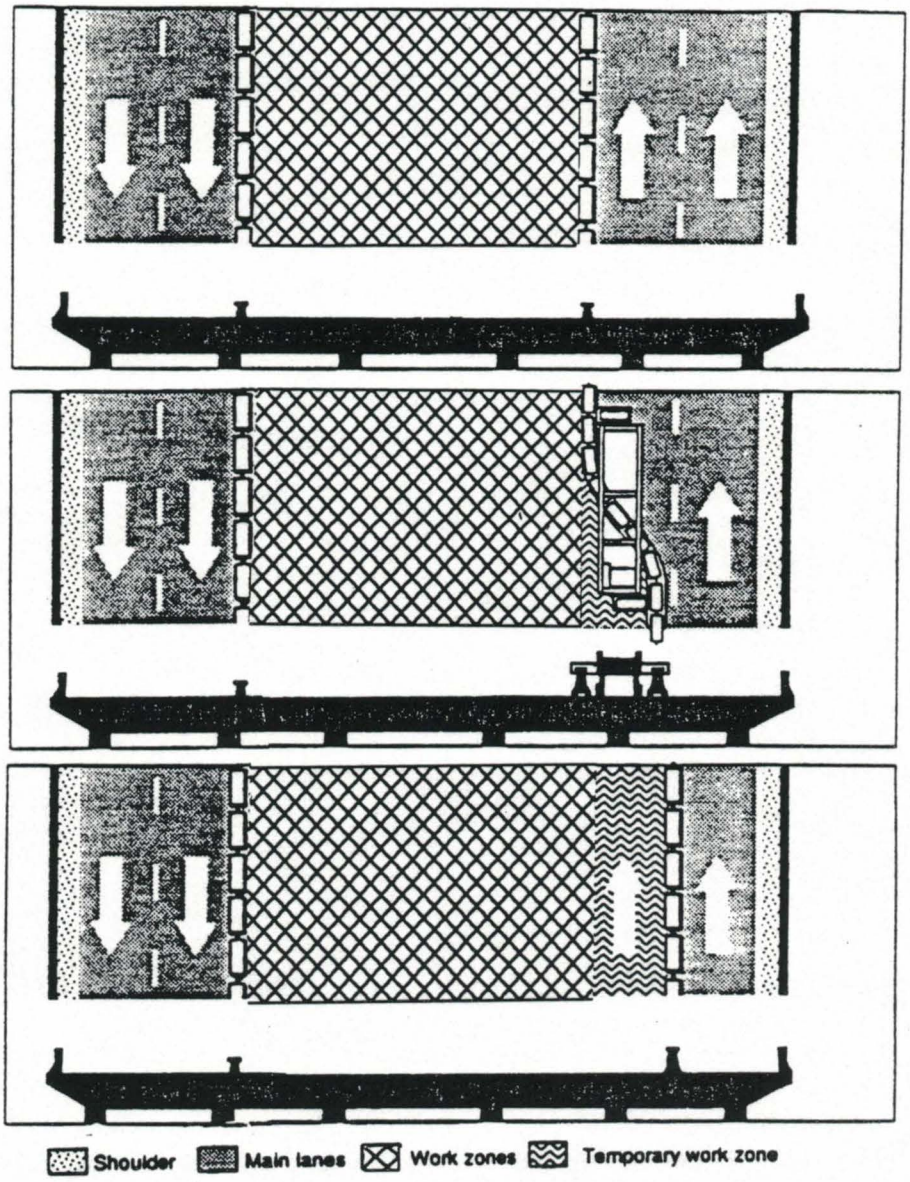


Figure 9. Barrier Wall Shift Sequence for Work in Median Area.

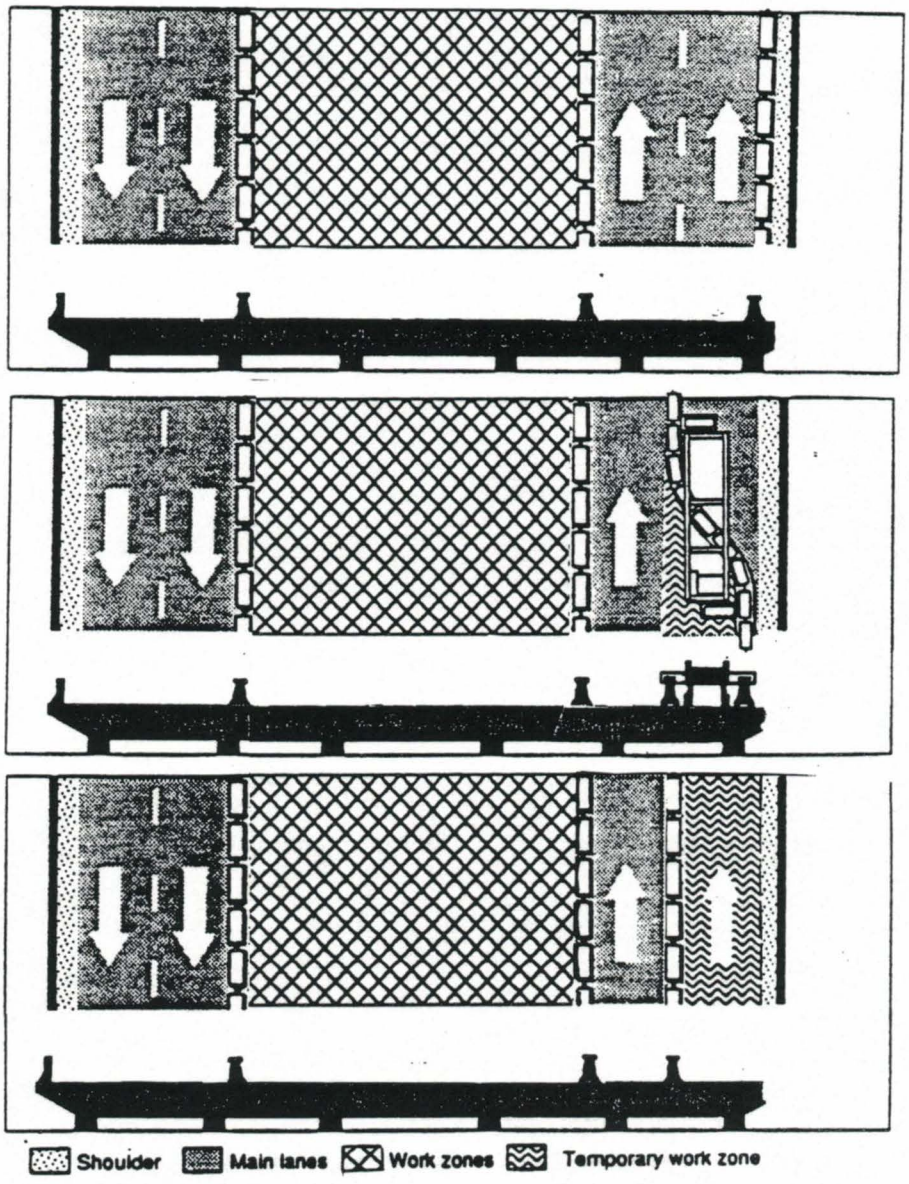


Figure 10. Barrier Wall Shift Sequence for Bridge Widening.

QMCB ACCIDENT HISTORY

The QMCB Barrier wall was involved in numerous collisions during the study. Of these, only twelve (12) collisions were reported to police. ODOT field personnel and contractor's employees estimated that unreported accidents exceeded those reported by approximately 2:1. Tire marks on the barrier wall face, fragments of automobile moldings, broken glass and plastic, etc. found along the QMCB wall indicated this to be the case.

Accident Study

To obtain information on as many collisions involving the barrier system as possible, a summary of fixed object accidents in the project area, was requested from the ODOT Traffic Engineering Division. The summary covered accidents in the project area, occurring while the QMCB System was deployed. Accident reports were then requested from The Oklahoma Department of Public Safety on listed accidents involving barrier walls. Selected items of information from these reports are summarized in Table 1.

Estimated vehicle speeds, at the time of contact, ranged from 10 to 65 mph. Accidents had already occurred, been investigated by Oklahoma Highway Patrol (OHP) troopers, and vehicles had been removed by the time the ODOT Research Division received reports on them. Angles of impact were not estimated or reported, as OHP Troopers do not ordinarily record this information. None of the impacting vehicles continued through the wall into the work area. With each collision, there was some barrier displacement, and straightening of the wall was required after each impact.

Had barrels, cones, or other easily moved channelization devices been used in place of the QMCB System, at least some of these vehicles would have continued into the work area. All twelve (12) of the reported accidents occurred at times when two (2) traffic lanes were open. Slightly over half (7 out of 12) of the reported accidents involved exceeding the posted speed limit of 45 mph. This could be interpreted as an indication of need for positive protection of work crews.(6)

Table 1. Reported Accidents Involving Barrier System.

DATE	TIME	# OF LANES OPEN	SPEED BEFORE CONTACT (mph)*	SPEED AT CONTACT (mph)*	DAMAGE TO VEHICLE ($)*	DAMAGE TO BARRIER WALL ($)*
6-20-88	1:25 A.M.	2	50	45	2,000	100
6-27-88	5:50 A.M.	2	45	40	1,850	50
9-15-88	7:15 A.M.	2	45	35	3,000	NONE
10-22-88	1:30 A.M.	2	55	50	4,500	NONE
11-3-88	7:40 A.M.	2	55	45	2,500	300
11-18-88	10:40 P.M.	2	65	65	10,000	NONE
12-27-88	11:32 A.M.	2	40	10	2,400	100
1-14-89	11:35 A.M.	2	35	10	500	50
2-13-89	8:05 A.M.	2	50	10	500	NONE
2-14-89	10:50 A.M.	2	45	15	800	NONE
4-27-89	1:55 P.M.	2	70	30	3,000	100
5-6-89	3:40 A.M.	2	85	45	500	500

note: * Estimated by Oklahoma Highway Patrol Trooper investigating the accident.

QMCB Impact Performance

According to ODOT field personnel and contractor's employees, the collisions where vehicles hit the barrier wall did no real damage to barrier segments, other than minor chips and spalls.

The QMCB wall had to be straightened after every impact. Maximum lateral displacement of the barrier wall, observed by field personnel, was one foot. Lateral displacement is determined by impact angle, pavement friction, pavement cross-slope, vehicle velocity, and vehicle weight (5).

Due to the requirements of this project, QMCB walls were placed along the outside or inside of traffic lanes. Because of this, any deflections caused by impacts were away from the traffic lanes. On future projects, protection requirements and barrier configurations will differ, and deflections could intrude into other driving lanes.

No damage to steel hinge pins or welded plate hinges was observed following any of the accidents. Scratches, approximately one (1) inch wide and 1/2 inch deep, running the length of three or four barrier segments were observed after several of the unreported accidents. These damages were not serious enough to require replacement of the segments involved.

*EST. BY OHP TROOPER INVESTIGATING ACCIDENT.

Figure 11. Speeds at Impact, Barrier Wall Collisions.

CONTRACT COSTS FOR QMCB SYSTEM

Project IR-240-1(324)000 required 14,600 L.F. of QMCB wall at a bid price of $73.00 per L.F. Cost of the TTV was $189,000.00 for a total cost of the QMCB System of $1,065,800.00 The system became ODOT property upon project completion, and will be used on future projects, so QMCB System costs are not applicable to this contract only.

The following comparison of QMCB costs on this project to costs for New Jersey Barrier is included for information purposes only. New Jersey and QMCB barriers are generally not used for the same purposes. Using New Jersey Barrier where it must be moved frequently is not effective use of time or equipment. Using QMCB Barrier in a stationary position is not effective use of this system.

The $73.00 per L.F. purchase cost for QMCB Barrier Wall is considerably higher than the $26.00 per L.F. cost of New Jersey Barrier (Figure 12.). A significant proportion (approximately 15 percent) of the QMCB segments now have chipped corners and/or chipping under the flanges (Figure 13.). According to Nielson's employees, this type of damage is due to wear during barrier wall shifts, and loading and unloading, rather than to collisions. This type of damage would indicate that the service life of QMCB segments will be related to the number of times placed on, or removed from worksites, and the number of times it is shifted. A shorter service life would be expected for QMCB segments, relative to that of New Jersey Barrier. If the expected shorter life proves to be correct, this will further increase the differences in cost, on a life cycle basis.

Cost for the realign/reset pay item on this contract was $0.04 per L.F. This compares to roughly $0.10 per L.F. for New Jersey Barrier. In most cases, the realign/reset pay item is a relatively small part of the total contract cost, for either type of barrier.

Data on the QMCB System involves only Project IR-240-1(324)000. For an accurate projection of QMCB system costs for future use, further study, involving more projects, will be required. Project IR-240-1(324)000, may not be representative of conditions on other projects. Neither the TTV or QMCB wall have been in service long enough to accurately determine factors such as service life, depreciation, or salvage value.

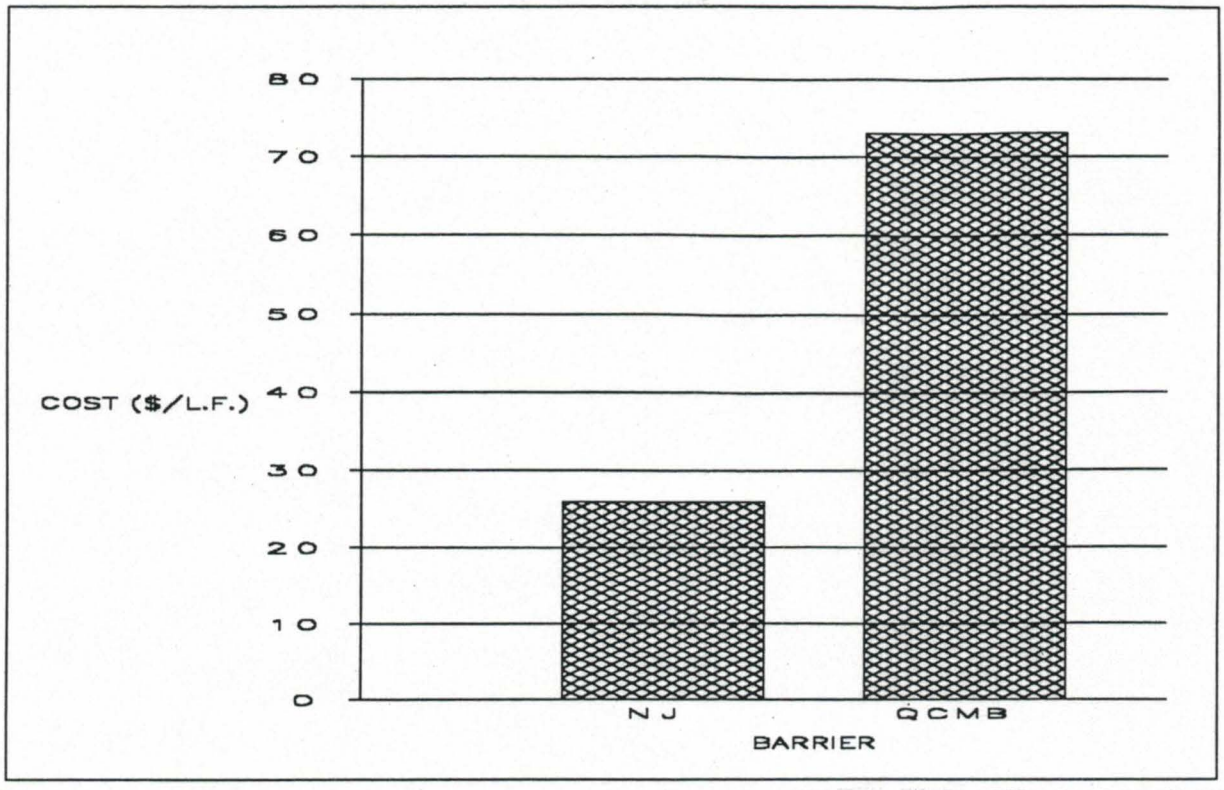


Figure 12. Purchase Price, New Jersey and QMCB Barrier.

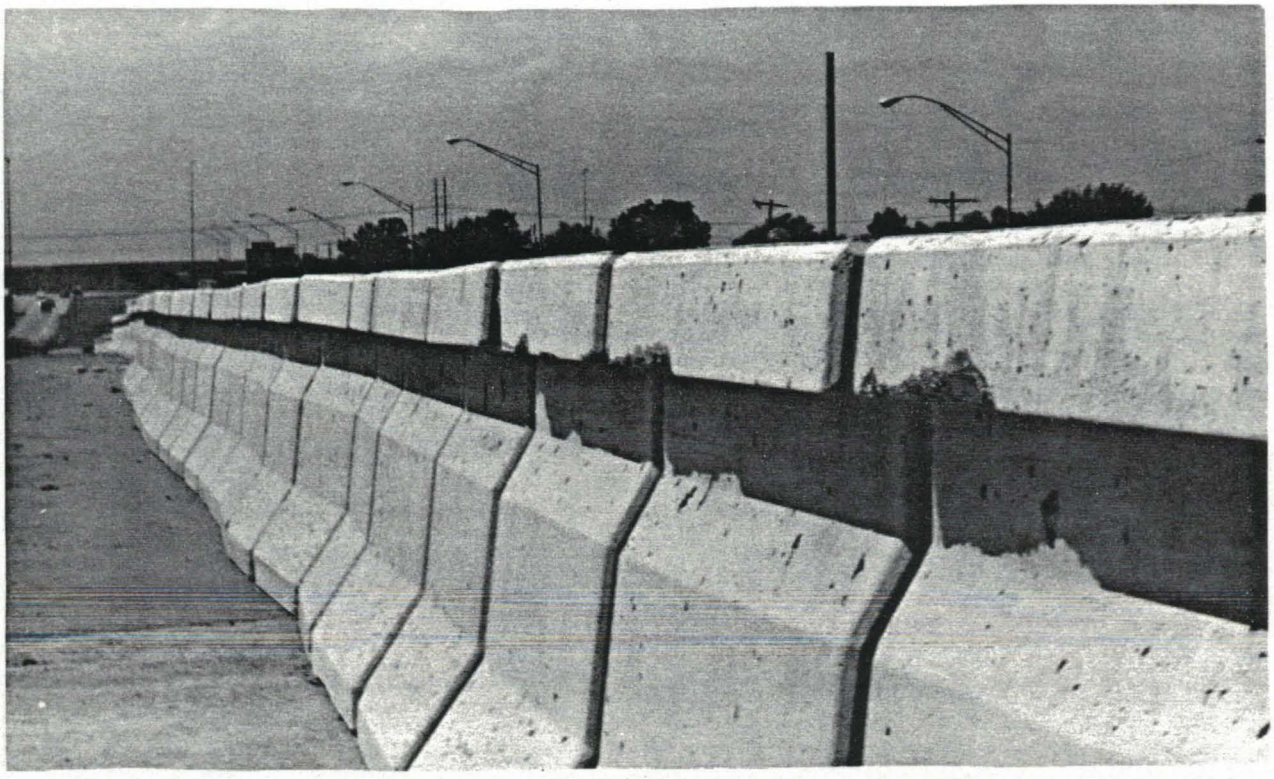


Figure 13. Chipping Under Flanges on Barrier Segments.

OPERATIONAL CONSIDERATIONS

Conditions on Project IR-240-1(324)000 made it necessary to protect both workers and motorists with a barrier system. The requirement that lanes be closed only after 7:00 PM, and be reopened before 7:00 AM, made a moveable barrier system practically the only way this could be accomplished. The purpose of the QMCB is to provide protection for work crews and equipment while allowing for rapid lateral barrier shifts when temporary lane closures are necessary. The QMCB system did this, and comments from work crews and field personnel indicated their appreciation for the protection.

Operation of the TTV

When the width of a barrier shift is changed, for example, from 14 feet to 6 feet, the number of carrier wheel assemblies must be changed. This requires removal or addition of assemblies which are bolted in place in the conveyor track (Figure 14). If the project requires barrier shifts of different widths, adequate time must be scheduled between shifts for the mechanic to make these changes.

Vendor's literature indicates that barrier wall can be shifted at speeds of 5 to 10 mph, and the TTV is capable of shifting barrier at this speed. However, it was the opinion of the contractor's employees on this project, that 3 to 5 mph is a better operating speed. The lower speed allows operators more time to stop if they observe objects on top of the wall, damaged barrier segments, or other potential problems. The 3 to 5 mph speed is adequate for any applications of the QMCB System anticipated by ODOT at this time.

The manufacturer's literature states that the TTV can transport a "chain" of up to 15 barrier segments (roughly 50 L.F.). TTV operators on this project indicated that it could not do this, as there was nothing to keep the barrier wall from sliding out of the TTV's conveyor track. Telephone conversation with one of the manufacturer's design engineers confirmed that the TTV does have this capability, but the barrier wall being moved must be secured by some means provided by the user, such as running a length of log chain, hooked to the TTV frame, around both ends of the "chain" of barrier segments.

The TTV was built mainly from John Deere brand components. Operating parts requiring replacement can ordinarily be obtained from local John Deere dealers without problems or delays. During work on IR-20-1(324)000, one of the hydraulic pumps had to be replaced at a time when postponing the barrier shift would have caused unacceptable delays. The mechanic was able to get a replacement from the first John Deere dealer he contacted. The same pump is used on combines, and John Deere dealers in this area normally keep it in stock.

TTV operators noticed that the barrier wall tended to "kink" during shifts when it was deployed on a noticeable curve. When this occurred, the TTV had to back up, then the wall had to be straightened by work vehicles, before the barrier shift could could continue (Figure 15). This happened frequently in areas where the wall was curved to flare it away from the traffic.

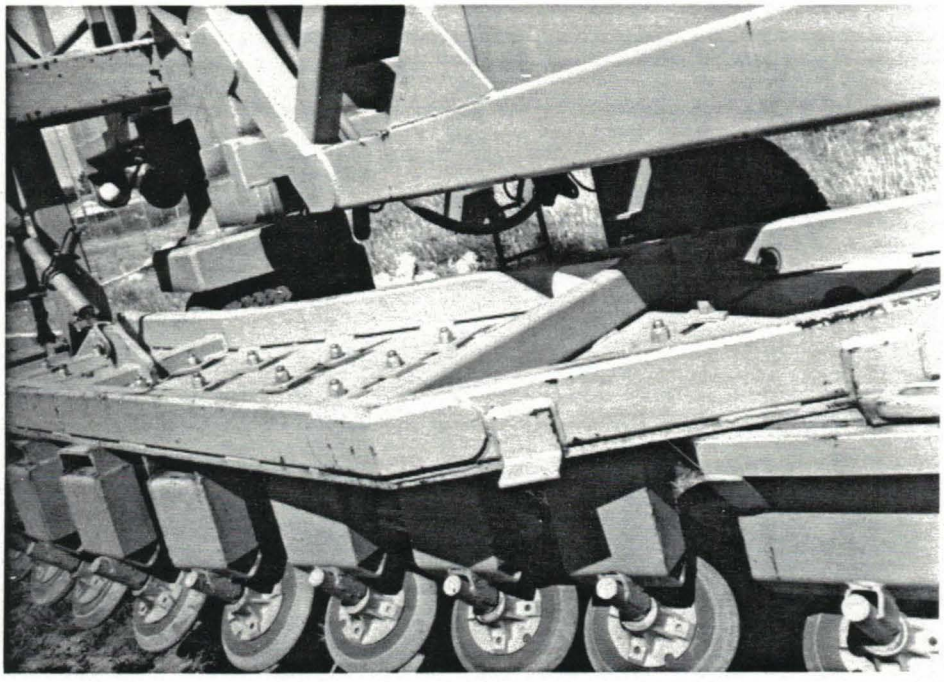


Figure 14. Carrier Wheel Assemblies.

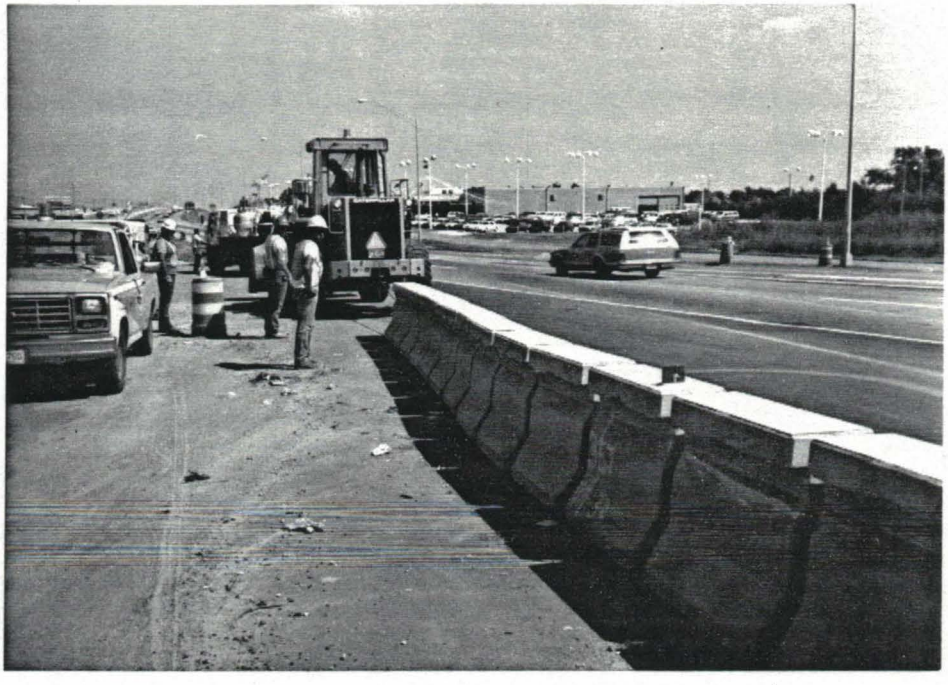


Figure 15. Straightening a "Kink" in the QMCB Wall.

QMCB Walls

Barrier segments have shown some signs of wear over the duration of this project. A fairly large proportion of the segments, roughly 15 per cent, have corners chipped off at the base or chipping under the flanges. During work on IR-240-1(324)000, approximately 15 segments (0.34 percent) were damaged severely enough so that they were no longer usable. According to Nielson's employees, all were damaged during loading, unloading, and stacking operations associated with initial placement and removal. Chipping under the flanges, and chipped corners occurred during barrier shifts.

QMCB End Protection

On Project IR-240-1(324)000, crash attenuator end protection was required for barrier walls positioned near traffic lanes. End protection consisted of arrays of sand barrels (Figure 16). When the barrier was shifted, the end protection had to be moved also. Sand barrels are not designed to withstand frequent moves, and they were often damaged during moves. The subcontractor responsible for traffic control moved the barrels using a small forklift (Figure 17). Barrels were placed on wooden pallets to allow for forklift handling. The pallets also broke frequently during moves. No collisions involving the sand barrel end protection occurred during work on this project.

Moving the end protection created a "bottleneck" situation when barrier walls were shifted. Sand barrels had to be moved one at a time by forklift. Relocating the sand barrel array took roughly 30 minutes. This had to be done in advance of barrier wall shifts which required approximately five (5) minutes per 1/2 mile of barrier wall shifted.

An improved type of end protection, designed to be quickly and easily moved, would streamline barrier shifting operations.

Figure 16. End Protection for QMCB Wall on Project IR-240-1(324)000.

Figure 17. Moving End Protection Prior to Barrier Wall Shift.

CONCLUSIONS

The QMCB System is most feasible for use on projects requiring barrier protection and frequent barrier wall shifts. Considerations which contribute to making the QMCB System a feasible alternative include: Requirements that lanes be closed only during certain hours, high ADT, necessity that work be done in close proximity to active traffic lanes, and dangerous work zone conditions.

The QMCB System may be used where stationary protection is required, but this is generally not effective use of the system, as New Jersey Barrier provides the same protection, at lower cost.

Barrier wall can best be shifted at speeds of 3 to 5 mph. While the system is capable of making shifts at slightly higher speeds, this (3 to 5 mph speed) is adequate for any projects anticipated by ODOT at this time.

The TTV has the capability of carrying up to 15 barrier wall segments, to place them where project work requires. This capability was not used on Project IR-240-1(324)000.

If advance coordination with local authorities is required when lane closures are to take place, then a formal planning procedure, such as critical path scheduling, must be followed. In some cases, this may have to be made a contract requirement.

Advance planning is also necessary to identify times when barrier shifts of different widths will be made. This must be done far enough ahead of time so that mechanics have time to add or remove the necessary number of carrier wheel assemblies. Shift width changes may be eliminated on some projects if work can be planned so that all shifts are one lane (12 feet) wide, or or some other "standard" width suited to project needs.

Damage to barrier segments in the form of chipped corners and flanges, spalls, etc. appears to be directly related to the number of times the barrier wall is shifted. Further study may show what the expected life of barrier segments is. Expected life will probably be in terms of number of barrier shifts.

Displacement of the QMCB wall can be expected each time the wall is struck by a motor vehicle. If future projects require that QMCB wall be placed in a narrow median, or between two lanes of traffic, this displacement may intrude into the lane on the opposite side of the wall.

Damage to barrier segments, due to vehicle impacts, was minor in all accidents occurring on this project.

No delays or interruptions, caused by the QMCB System, occurred on this project. The TTV is relatively easy to work on, and parts are readily available. When the barrier wall was hit, or "kinks" in the wall occurred, contractor's employees were able to straighten it quickly, using work equipment.

Moving end protection prior to barrier shifts, causes delay with each shift. Development of mobile or portable portable end protection would eliminate the delays.

RECOMMENDATIONS

1. Consideration should be given to using the QMCB System on projects located in areas with high ADT, where work is in close proximity to traffic, or where frequent, short term lane closures are expected.

2. It is recommended that barrier shifts be made at speeds of 3 to 5 mph.

3. On projects where the TTV is expected to carry barrier segments for placement on the jobsite, a gate or pin assembly should be fabricated to prevent the "chain" of segments from slipping out of the conveyor track during movement.

4. Where barrier shifts must be coordinated in advance with local authorities, critical path, or other formal scheduling procedures, should be used.

5. Deflections can be expected each time the QMCB wall is hit. Ample median width, or space between the barrier wall and work area should be provided to contain the deflections

6. After most accidents where vehicles hit the barrier wall, the vehicles slide off the wall without serious damage, and are able to continue on. Because of this, the wall should be inspected for deflections at the beginning of each work shift. Corrections should be made when deflections are discovered.

7. Further study should be done on damage to barrier segments. The purchase price of QMCB wall is relatively high, and it may be cost effective to add side plates, or other additional reinforcement, to the segments.

8. Where possible, QMCB wall should be deployed in straight line configurations. The wall tends to "kink" during barrier wall shifts when deployed on a noticeable curve. If placement on a curve is required, the radius of the curve should be as large as possible.

9. Work should be planned so that the number of shift width changes is minimized. Where shift width changes must be made, adequate time between shifts must be provided so that the mechanics have time to add or remove carrier wheel assemblies to accommodate the new width.

10. Crash attenuator type end protection, designed to be quickly and easily moved, should be developed for use with the QMCB system.

REFERENCES

1. Barrier Systems Incorporated, "Quickchange Series 200 Moveable Concrete Barrier (MCB) for Protection of Construction Zones with Traffic on One Side", Barrier Systems, Inc., 1987.

2. J.L. Graham, J.R. Loumiet, and J. Migletz, "Portable Concrete Barrier Connectors", FHWA-TS-88-006, November, 1987.

3. Barrier Systems Incorporated, "TTV Model 3 Owners Manual", Barrier Systems, Inc., 1988.

4. M.T. Stanley, "In-Service Performance of the Quickchange Moveable Concrete Barrier System", Interim Status Report, 1987 - June, 1989, North Carolina D.O.T., August, 1989.

5. J.E. Bryden and N.J. Bruno, "Moveable Concrete Median Barrier: Risk of Deflection into Opposing Traffic", FHWA/NY/RR-88/145, December, 1988.

6. H.E. Ross, T.L. Kohutek, and J. Pledger, "Guide for Selecting, Locating, snd Designing Traffic Barriers, Volume I, Guidelines", FHWA-RD-7650, February, 1976.

APPENDIX A, SPECIAL PROVISIONS.

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
MOVABLE CONCRETE MEDIAN BARRIER
IR-240-1(324)000

These Special Provisions revise, amend, and where in conflict, supersede applicable Sections of the Standard Specifications for Highway Construction, Edition of 1976, and the Supplement thereto, Edition of 1984.

885.01. DESCRIPTION. This work shall consist of the construction, placement, maintenance and all handling including realignment, resetting, removal and transportation of movable concrete median barriers at the locations designated on the Plans or as required by the construction sequence for work zone protection. Movable concrete median barriers furnished by the Contractor shall be in accordance with the details shown on the Plans and applicable Specifications herein. Movable concrete median barriers to be furnished by the Department will be available at sites designated on the Plans.

885.02. MATERIALS. All materials used in the construction of movable concrete median barriers shall meet the following requirements specified in Section 700-Materials.

Portland Cement Concrete	701
Reinforcing Steel	723

885.03. EQUIPMENT. The transfer and transport vehicle for placing, resetting and removing the Movable Concrete Median Barriers at the project site shall be furnished in accordance with Special Provisions 886-1.

885.04. CONSTRUCTION METHODS. Prior to beginning casting of the movable concrete median barriers, the Contractor shall advise the Engineer of the casting site and the date casting will begin.

The mixing, placement, finishing and curing of concrete median barriers shall be in accordance with Section 627.

Should the Contractor propose to furnish movable concrete median barriers that have been previously constructed, he shall provide written certification that the barrier sections conform to the requirements specified herein.

Barrier sections, including the required hinges and hinge pins, which are damaged or lost during the process of fabrication, curing, handling or placement shall be repaired or replaced at the Contractor's expense.

At such time as the movable concrete median barriers are no longer required for protection of the work site or motoring

public on the project, the barriers and all hardware shall become the property of the Department and shall be removed to storage areas designated on the Plans. Upon delivery to a storage area, the barrier sections shall be neatly stockpiled and all hardware stored in sturdy containers marked for future identification.

885.05. METHOD OF MEASUREMENT. Movable Concrete Median Barriers will be measured for payment as follows:

(a) The work performed and materials required to construct the movable concrete median barriers, transport and install the barriers at the initial locations shown on the Plans will be measured for payment by the linear foot at the Contract unit price for Movable Concrete Median Barrier.

(b) The work performed in realignment and resetting of the barriers in a new location as required by the construction sequence, will be measured for payment by the linear foot at the Contract unit price for Movable Concrete Median Barrier (Realign/Reset).

(c) The work performed in moving concrete median barriers furnished by the Department from storage sites and installing the barriers in place on the project site; or the work performed in removing and transporting the barriers from the project site to a designated storage area, will be measured for payment by the linear foot at the Contract unit price for Movable Concrete Median Barrier (Remove/Install).

(d) The work performed to move concrete median barriers within the project limits a distance which exceeds the capability of the transfer and transport equipment, will be measured for payment by the linear foot at the Contract unit price for Movable Concrete Median Barrier (Relocate).

885.06. BASIS OF PAYMENT. Accepted quantities of Movable Concrete Median Barrier, measured as provided above, will be paid for at the Contract unit price for:

(A)	MOVABLE CONCRETE MEDIAN BARRIER	L.F.
(B)	MOVABLE CONCRETE MEDIAN BARRIER (REALIGN/RESET)	L.F.
(C)	MOVABLE CONCRETE MEDIAN BARRIER (REMOVE/INSTALL)	L.F.
(D)	MOVABLE CONCRETE MEDIAN BARRIER (RELOCATE)	L.F.

which shall be full compensation for furnishing all materials, tools, equipment, labor and incidentals to complete the work as specified.

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
MOVABLE CONCRETE MEDIAN BARRIER
TRANSFER AND TRANSPORT VEHICLE
IR-240-1(324)000

These Special Provisions revise, amend, and where in conflict, supersede applicable Sections of the Standard Specifications for Highway Construction, Edition of 1976, and the Supplement thereto, Edition of 1984.

886.01. DESCRIPTION. This work shall consist of furnishing a Movable Concrete Median Barrier Transfer and Transport Vehicle meeting the requirements specified herein and providing for the maintenance and operation of the vehicle during the time it is required on the project. The vehicle shall be a self-propelled unit designed specifically for the transfer and transport of Movable Concrete Median Barriers specified in accordance with Special Provisions 885-1. The Contractor shall furnish a new unit for use on the project.

The Movable Concrete Median Barrier Transfer and Transport Vehicle shall be a QUICKCHANGE (T.M.) unit, or an approved equal. The QUICKCHANGE (T.M.) unit may be purchased from:

Barrier Systems, Inc.
408 Coloma
P.O. Box 125
Sausalito, California 94966
(415) 331-3137

NOTE: This vehicle is a patented and patent-pending product.

The unit shall be capable of picking up and moving continuous lengths of movable concrete median barrier a minimum of 6 feet and a maximum of 16 feet laterally across the roadway. The movement of the barrier shall be accomplished at a forward operating speed of 5-10 MPH. The unit shall also be capable of picking up and moving a minimum of 50 feet of continuous barrier at one time and shall have the capability to lift the barrier thirty inches vertically above the roadway. No portion of the unit shall extend into the adjacent traffic lane during the transfer operation.

886.04. CONSTRUCTION METHODS. The Movable Concrete Median Barrier Transfer and Transport Vehicle shall be used for the positioning of the barrier at locations shown on the Plans, as required for work zone protection during the construction sequence, or as directed by the Engineer.

The Contractor shall provide a trained and responsible operator to operate the unit on the project.

When not in use, the unit will be stored in an approved, secure storage area.

The Contractor shall be responsible for the repair or replacement of the unit should it become damaged or destroyed during the period it is required on the project. The Contractor shall perform all routine maintenance recommended by the manufacturer and facilitate any repairs to minimize interruptions of the project schedule.

Upon completion of the project the Movable Concrete Median Barrier Transfer and Transport Vehicle will become the property of the Department. Prior to the transfer of ownership, the Contractor shall clean the unit and repair all damages affecting the operation and appearance. The unit shall be delivered to a site designated on the Plans. All service manuals, operating manuals, special tools and spare parts shall be delivered with the unit.

886.05. MEASUREMENT. Measurement of Movable Concrete Median Barrier Transfer and Transport Vehicles will be by the unit provided on an each basis.

886.06. BASIS OF PAYMENT. Accepted quantities measured as provided above will be paid for at the Contract unit price for:

MOVABLE CONCRETE MEDIAN BARRIER
TRANSFER AND TRANSPORT VEHICLE EA.

which shall be full compensation for furnishing all materials, tools, equipment, labor and incidentals to complete the work as specified.

APPENDIX B, ACCIDENT STUDY.

TABULATION OF ACCIDENT DATA FROM 04-01-88 TO 06-30-89 RUN DATE: 10/10/89

FIXED OBJECT ACCIDENTS ON I240 FROM I44 EXTENDING E. TO I35, OKLA CO STUDY LENGTH : 4.19

ACCIDENT SEVERITY

	1988				1989				1990				1991				1992			
	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL
ACCIDENTS		1	7	8		2	3	5												
PERSONS		2		2		2		2												

STUDY TOTAL(SEVERITY)

	FATAL	INJURY	PROPERTY DAMAGE	TOTAL
ACCIDENTS		3	10	13*
PERSONS		4		4

ACCIDENT TYPE & DAMAGE CAUSED

COLLISION TYPE	1988				1989				1990				1991				1992			
	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL	FAT	INJ	P-D	TOTAL
OVR-TRN(IN-RD)																				
PEDESTRIAN																				
PARKED-VEHICLE																				
RAILROAD-TRAIN																				
ANIMAL																				
FIXED-OBJECT		1	7	8		2	3	5												
RAN-OFF-ROAD																				
S-S(SAME-DIR)																				
REAR-END																				
HEAD-ON																				
S-S(OPP-DIR)																				
ANGLE(TURN)I																				
ANGLE(TURN)NI																				
ANGLE(I)																				
ANGLE(NI)																				
OTHER																				
TOTAL(P.D.)	$28,850				$3,250															

STUDY TOTAL(ACCIDENT TYPE)

	FATAL	PERCENT	INJURY	PERCENT	PROPERTY DAMAGE	PERCENT	TOTAL	PERCENT
OVR-TRN(IN-RD)								
PEDESTRIAN								
PARKED-VEHICLE								
RAILROAD-TRAIN								
ANIMAL								
FIXED-OBJECT			3	100.0	10	100.0	13	100.0
RAN-OFF-ROAD								
S-S(SAME-DIR)								
REAR-END								
HEAD-ON								
S-S(OPP-DIR)								
ANGLE(TURN)I								
ANGLE(TURN)NI								
ANGLE(I)								
ANGLE(NI)								
OTHER								
TOTAL			3	100.0	10	100.0	13	100.0

STUDY TOTAL(DAMAGE CAUSED) $32,100

*** Includes one (1) accident where a permanent barrier wall (not QMCB) was hit.**

TABULATION OF ACCIDENT DATA FROM 04-01-88 TO 06-30-89 RUN DATE: 10/10/89

FIXED OBJECT ACCIDENTS ON I240 FROM I44 EXTENDING E. TO I35, OKLA CO STUDY LENGTH : 4.19

SPEED CONDITIONS

TYPE OF VEHICLE	OPERATING SPEED										TOTAL	PERCENT
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+	UNKNOWN		
SINGLE UNIT (NORMAL)	1	3	1	2	3	1					11	78.5
SINGLE UNIT (LARGE)		1			1		1				3	21.4
DUAL UNIT												
OTHER												
TOTAL	1	4	1	2	4	1	1				14	100.0
PERCENT	7.1	28.5	7.1	14.2	28.5	7.1	7.1				100.0	

ACCIDENT OCCURRENCE

DAY	HOUR OF THE DAY																								TOTAL	PERCENT
	<----AM---->												<----PM---->													
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12		
MON	1				1			1																	3	23.0
TUE										1	1														2	15.3
WED																										
THU							2						1					1							4	30.7
FRI																						1			1	7.6
SAT	1		1								1														3	23.0
SUN																										

	EARLY MORNING-SUNRISE	MORNING PEAK	MID MORNING-MID AFTERNOON	AFTERNOON PEAK	EVENING-LATE NIGHT	TOTAL	100.0
TOTAL	4	3	4	1	1	13	
PERCENT	30.7	23.0	30.7	7.6	7.6	100	

POTENTIAL INFLUENCING CONDITIONS

ROADWAY CONDITIONS	LIGHTING CONDITIONS					TOTAL	PERCENT
	DAYLIGHT	DARKNESS	TWILIGHT	LIGHTED	UNKNOWN		
DRY	4	2		1		7	53.8
WET(WATER)	4	1				5	38.4
WET(ICE OR SNOW)	1					1	7.6
MUDDY							
NOT REPORTED							
TOTAL	9	3		1		13	100.0
PERCENT	69.2	23.0		7.6		100	

WEATHER CONDITIONS	TOTAL	PERCENT
CLEAR	2	15.3
PARTLY CLOUDY	4	30.7
OVERCAST	2	15.3
RAINING	5	38.4
OTHER		
TOTAL	13	100.0

TABULATION OF ACCIDENT DATA FROM 04-01-88 TO 06-30-89 RUN DATE: 10/10/89

FIXED OBJECT ACCIDENTS ON I240 FROM I44 EXTENDING E. TO I35, OKLA CO STUDY LENGTH : 4.19

CAUSE OF ACCIDENT	OFFENDING DRIVERS CONDITION																		ACCIDENT SEVERITY				
	APPARENTLY NORMAL			ALCOHOL INVOLVED						SLEEP SUSPECTED			PHYSICAL DEFECT			OTHER CONDITION							
				ABILITY IMPAIRED			ODOR DETECTED																
	FAT	INJ	P-D	FAT	INJ	P-D	FAT	INJ	P-D	FAT	INJ	P-D	FAT	INJ	P-D	FAT	INJ	P-D	FAT	INJ	P-D	TOTAL	PCT
F-YIELD																							
F-STOP																							
F-SIGNAL																							
IMP-TURN																							
IMP-START																							
IMP-STOP																							
IMP-BACK																							
IMP-PARK																							
IMP-PASS																							
IMP-LN-CHG																							
L-CENTER																							
FOL-CLOSE																							
UNSAF-SPD		1	7					1	2											2	9	11	84.6
D-W-I																							
INATT																							
NEG-DRVING																							
DEF-VEH																							
WRNG-WAY																							
NO-IMP-ACT			1																		1	1	7.6
OTHER		1																		1		1	7.6
TOTAL		2	8					1	2											3	10	13	100.0
PERCENT		15.3	61.5					7.6	15.3											23.0	76.9	100	

OKLAHOMA DEPARTMENT OF TRANSPORTATION — HIGHWAY TABULATION — TRAFFIC ENGINEERING DIVISION

ACCIDENT CONCENTRATION LISTING

COUNTY: (55) OKLAHOMA — FIXED OBJECT ACCIDENTS ON I240 FROM I44 EXTENDING E. TO I35, OKLA CO — 04-01-88 THRU 06-30-89

CITY	CS #	INT #	MILE POST	DIAG CODE	LOCATION DESCRIPTION	SPECIAL FEATURES	INT REL	D1	D2	# VE	PEOPLE IN-FAT	PROP DMG	TYPE ACCIDENT	CAUSE OF ACCIDENT	CONDITIONS LIGHT	ROAD	SEV	DATE
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0040	00000		CONSTRUCTION	NO	E		1		5100	F-O(BARRIER)	UNSAF-SPD	DARK	DRY	PD	10-22-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0049	00000		CONSTRUCTION	NO	E		1		2000	F-O(RETN WALL)	UNSAF-SPD	LIGHT	DRY	PD	06-20-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0051	00000			NO	E		1		10000	F-O(RETN WALL)	UNSAF-SPD	DARK	WET	PD	11-18-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0054	00000		CONSTRUCTION	NO	W		1		1850	F-O(RETN WALL)	NO-IMP-ACT	DYLGT	DRY	PD	06-27-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0060	00000		CONSTRUCTION	NO	W		1		3000	F-O(RETN WALL)	UNSAF-SPD	DYLGT	WET	PD	09-15-88
70	71	00	0060	00000		CONSTRUCTION	NO	W		1	2	2500	F-O(RETN WALL)	OTHER	DYLGT	DRY	INJ	12-27-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST		S.WESTERN OP *83*												
70	71	00	0253	30120	S.WESTERN OP *83*	TERM LOC RIT YES	NE			1		700	F-O(BARRIER)	UNSAF-SPD	DYLGT	WET	PD	06-16-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0263	00000		CONSTRUCTION	NO	E		1	1	1000	F-O(BARRIER)	UNSAF-SPD	DARK	DRY	INJ	05-06-89
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0313	00000		CONSTRUCTION	NO	E	E	2		3700	F-O(RETN WALL)	UNSAF-SPD	DYLGT	DRY	PD	11-03-88
(70)	OKLAHOMA CITY		I-240	I-240 EAST														
70	71	00	0343	00000		CONSTRUCTION	NO	E		1		550	F-O(RETN WALL)	UNSAF-SPD	DYLGT	IC-S	PD	01-14-89
70	71	00	0343	00000			NO	E		1		500	F-O(RETN WALL)	UNSAF-SPD	DYLGT	WET	PD	02-13-89
70	71	00	0343	00000		CONSTRUCTION	NO	E		1		800	F-O(RETN WALL)	UNSAF-SPD	DYLGT	WET	PD	02-14-89
(70)	OKLAHOMA CITY		I-240	I-240 EAST		US-77 SHIELDS EB EX *86*												
70	71	28	0365	00000	SHIELDS EB EX *86*	RAMP GORE	NO	E		1	1	400	F-O(RETN WALL)	UNSAF-SPD	DYLGT	DRY	INJ	04-27-89

RUN DATE: 10/10/89