HAZARD MITIGATION TECHNICAL ASSISTANCE PROGRAM
CONTRACT NO. EMW-2000-CO-0247

TASK ORDER # 007
HARRISON CENTRAL HIGH SCHOOL STRUCTURAL WIND RETROFIT ASSESSMENT REPORT
FEMA-1604-MS

FINAL REPORT

AUGUST 29, 2006

SUBMITTED TO:

FEDERAL EMERGENCY MANAGEMENT AGENCY
REGION IV
ATLANTA, GA

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FORWARD

Hurricane Katrina will be recorded as one of the worst natural disasters in the history of the United States, producing catastrophic damage and untold casualties in and along the Mississippi, Alabama, and Louisiana Gulf Coast region.

Katrina became a hurricane off Florida's southeast coast and crossed its shoreline as a Category 1 hurricane. After passing over the Florida Straits, Katrina entered the warm Gulf Coast waters and quickly became a Category 5 hurricane. According to the National Hurricane Center, Katrina weakened to a Category 3 event just before the eye of the hurricane made landfall the first time in Louisiana and finally in Waveland, Mississippi. The hurricane inflicted significant damage on the Gulf Coast with punishing winds and record storm surge.

While the total estimate of damages is being collected, it is clear that most of the damage was caused by the record storm surge, currently estimated at over 30 feet above North American Vertical Datum of 1988 (NAVD 88), one of the highest recorded in American history. Katrina produced a record-breaking storm surge that was devastating to the coastal areas of Mississippi.

The purpose of this task is to provide the Department of Homeland Security (DHS) and Federal Emergency Management Agency (FEMA) with Structural Analyses of Mississippi Coastal Counties Schools, Community Centers, Critical Facilities and other buildings to be wind retrofitted.

The scope of this task included:

1. Identify building(s) or portions of building(s) on the school campus that have the possibility of being feasibly retrofitted to meet American Society of Civil Engineers Standard, ASCE 7-02 – Minimum Design Loads for Buildings and Other Structures;

2. Perform detailed structural analyses and ascertain retrofit procedures for identified structures to survive design wind speeds and pressures per ASCE 7-02. Identify if any building(s) or portions of building(s) can be retrofitted to meet the shelter design standard FEMA 361 – Design and Construction Guidance for Community Shelters;

3. Perform a cost estimate to retrofit the identified structures to meet ASCE 7-02 standards.

EXECUTIVE SUMMARY

This report presents a site summary, structural analysis methodology, cost analysis and final conclusions and recommendations related to wind retrofitting the Harrison Central High School, a school in Harrison County School District, located at 15600 School Road, in Gulfport, Harrison County, Mississippi.

A site visit was performed at Harrison Central High School on June 12, 2006 to evaluate the buildings located at the site and to determine which buildings could possibly be retrofitted to meet the requirements of the ASCE 7-02 Standard for wind loading. Upon inspecting the buildings located at the site, it was determined that only Buildings 6 & 7 could be considered for analysis and retrofit. None of the buildings at the site were identified as candidates for retrofit to meet the FEMA 361 Standard. Buildings 6 & 7 were designed in 1994 & 1997, respectively.

Items required to retrofit Building 6 at Harrison Central High School to the ASCE 7-02 Design Standard, could be expected to cost the following:

Foundation and Wall System:	$567,000
Doors and Window Systems (19 windows & 4 doors):	$137,000
Roof System:	$459,000
Rooftop Units	$18,000

Total Estimated Costs (2006): $1,181,000

It is possible that as much as 10% could be saved on Building 6 by letting all work under one single contract.

Items required to retrofit Building 7 at Harrison Central High School to the ASCE 7-02 Design Standard, could be expected to cost the following:

Foundation and Wall System:	$564,000
Doors and Window Systems (10 windows & 2 doors):	$120,000
Roof System:	$148,000
Rooftop Units:	$18,000

Total Estimated Costs (2006): $850,000

It is possible that as much as 13% could be saved on Building 7 by letting all work under one single contract.

STRUCTURAL ANALYSIS OF BUILDINGS

Standards of Use

The analyses of the identified buildings utilize the ASCE 7-02 Design Standard, which specifies the design wind speed and the combination of loads that are to be used in the design of the structure. The wind pressures calculated in accordance with ASCE 7-02 are applied to tributary areas on the structure, resulting in forces at connections and stresses in structural members. In accordance with ASCE 7-02, the site is located in a region where the design wind speed is 140 mph (3-second gusts).

The evaluations were limited to the buildings included in this report. The structural evaluation of each of the buildings throughout the site is based on visual observation of the buildings structural components as well as a review and analysis of the existing plans provided for our use. Structural components concealed in wall panels and hard ceilings or stucco could not be observed or validated. No testing of structural members was performed. As a routine matter, in order to avoid possible misunderstanding, nothing in this report should be construed directly or indirectly as a guarantee for any portion of the structure. To the best of our knowledge and ability, this report represents an accurate appraisal of the present condition of the buildings and the retrofits necessary to have them meet the ASCE 7-02 Standard for wind loading.

Preliminary Site Analysis

A site visit was performed at Harrison Central High School, Figure 1, on June 12, 2006 to evaluate the buildings and determine which buildings could possibly be retrofitted to meet the requirements of the ASCE 7-02 Standard for wind loading.

Most of the roof decks on the buildings located at the site utilize two to three inch fiber board roof panels supported by structural steel angles or similar steel supports (see Photograph 1 in Appendix B). Once this type of deck is exposed to moisture for a prolonged period of time, the fiber board loses most of its strength and becomes soft (see Photograph 2 in Appendix B). Also, this type of system does not perform well in uplift; the bulb tees that support the deck are capable of supporting gravity loads but do not have any holding capacity when uplift pressure is applied, such as that applied by wind as it goes over the roof. With the moisture damage, it is unlikely that this roof deck can transfer lateral loads as a roof diaphragm. This deck is also easily penetrated by wind borne debris.

There is no feasible way to retrofit a fiber board roof panel system. The best solution to this problem is to remove the existing fiber board deck and replace it with a 1½-inch steel roof deck and acoustical panels. The replacement of a fiber deck with a steel deck would be too cost-prohibitive, and thus is not considered an option in this report.

The walls of the buildings located at the site consist of masonry load-bearing or masonry infill walls. The reinforcement of the existing masonry walls could not be observed or validated.

The foundations of the buildings located on the site could not be observed or validated. However, these types of structures typically are constructed on continuous spread footings.

Upon inspection of the buildings located at the site, it was determined that only Buildings 6 & 7 could be considered for analysis and retrofit to meet the ASCE 7-02 Design Standard. These buildings have a metal deck system in lieu of the fiber board roof panel system, and are relatively easy to retrofit. None of the buildings at the site were identified as candidates for retrofit to meet the FEMA 361 Standard.

Roof Framing System –Building 6

The existing roofing system utilizes a metal deck and bar joists supported by load-bearing exterior and interior masonry block walls. The roofing will need to be removed in order to reattach the roof deck throughout with sufficient rigidity to allow it to act as a diaphragm. Based on our analysis, the individual roof deck panels need to be fastened to the joists at each rib. Furthermore, the sidelap connection to the adjacent panels on each side needs to be accomplished with sufficient frequency to achieve adequate diaphragm action. When this retrofit has been completed, then the building should be re-roofed and sealed at all flashings and penetrations. See Figure 4 in Appendix C.

The roof framing is adequate to resist the wind uplift forces with the exception of the 20K5 steel joists, which are too weak for the design loads specified in the ASCE 7-02 Design Standard. They will require reinforcement by the addition of two-1/2” diameter steel rods welded to the underside of the top chord of the joists throughout the entire span, including into the bearing ends. The bottom chords will also require the addition of a ¼”x3” steel plate welded to the underside of the bottom chord in the center 15 feet of each span (see Figure 5 in Appendix C). The trusses should also be inspected in the field to determine the presence of horizontal bridging at each ten feet of span for each joist; such bridging should be installed if not present (see Figure 7 in Appendix C). Furthermore, diagonal braces should be provided at mid-span of each joist with bolted connections at chords and intersections if not present (See Figure 6 in Appendix C). These modifications will allow the roof framing to resist the wind uplift forces dictated by the ASCE 7-02 Standard.

Wall System – Building 6

The load-bearing masonry walls will require enhancement to meet the ASCE 7-02 Standard for wind design. Currently, the walls contain insufficient reinforcement to meet wind load requirements. Proper wall reinforcement allows the wind loads on the roof and walls to be transmitted to the building foundation. Based on our analysis, this building will require #6 bars at 16” spacing in all 6” load-bearing perimeter walls within 5 feet of the building corners, and #6 bars at 24” spacing in the remaining perimeter walls and load-bearing interior walls. In the event that existing reinforced cells are located as work progresses, then the new bars may be moved 16” from the existing reinforced cell and reinforcement of the walls may continue at the increments specified. All the reinforced cells should then be fully grouted once the reinforcement is in place in order to make the new steel effective. The existing bond beams will not require enhancement provided that the above vertical reinforcement is added to the masonry walls as indicated.

According to the construction documents provided to us, all existing opening jambs appear to be reinforced. Based on our experience, the masonry shear walls should have adequate strength to meet the ASCE 7-02 Standard for wind design provided that all the opening jambs are reinforced and the above reinforcement enhancements are properly carried out.

Door and Window Systems – Building 6

The exterior windows and doors also require enhancement to meet the ASCE 7-02 Standard for wind design. All exterior windows and doors of Building 6 should be replaced to withstand the positive pressures of +45 psf and negative pressures of -60 psf. As an alternative, storm shutter systems can be installed in lieu of new window systems. Provide window, door, storm shutter, and frame systems that comply with performance requirements indicated, as demonstrated by testing manufacturer’s assemblies in accordance with the International Building Code Test Standards ASTM E1886-05 dated 01-Jan-2005 "*Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials"* and ASTM E1996-05 dated 01-May-2005 *"Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes"*.

Rooftop Units – Building 6

There are many mechanical units sitting on the roof of the building. These units do not appear to be tied down sufficiently to the roof structure. During a hurricane, they may become wind borne missiles and destroy the roofing. All roof top mechanical units should be adequately tied down to the main structural members.

Foundation Systems – Building 6

According to the construction documents provided to us, all existing foundations appear to be adequate. Based on our experience, the spread footings should have adequate strength to meet the ASCE 7-02 Standard for wind design provided that they have been constructed in accordance with the construction documents.

Roof Framing System –Building 7

Based on our analysis and the construction documents provided to us, the roof deck is connected throughout to the roof framing system with sufficient rigidity to allow it to act as a diaphragm in order to resist the wind loads dictated by the ASCE 7-02 Design Standard.

The roof framing is adequate to resist the wind uplift forces with the exception of the 18K3 steel joists, which are too weak for the loads specified in the ASCE 7-02 Design Standard. They will require reinforcement by the addition of two-1/2" diameter steel rods welded to the underside of the top chord of the joists throughout the entire span, including into the bearing ends. The bottom chords will also require the addition of a ¼"x3" steel plate welded to the underside of the bottom chord in the center 16 feet of each span (see Figure 5 in Appendix C). The trusses should also be inspected in the field to determine the presence of horizontal bridging at each ten feet of span for each joist; such bridging should be installed if not present (see Figure 7 in Appendix C). These modifications will allow the roof framing to resist the wind uplift forces dictated by the ASCE 7-02 Standard.

Wall System – Building 7

The load-bearing masonry walls will require enhancement to meet the ASCE 7-02 Standard for wind design. Currently, the walls contain insufficient reinforcement to meet wind load requirements. Proper wall reinforcement allows the wind loads on the roof and walls to be transmitted to the building foundation. Based on our analysis, this building will require #6 bars at 48" spacing at all load-bearing perimeter and interior walls. In the event that existing reinforced cells are located as work progresses, then the new bars may be moved 16" from the existing reinforced cell and reinforcement of the walls may continue at the increments specified. All the reinforced cells should then be fully grouted once the reinforcement is in place in order to make the new steel effective. All door jambs should also be reinforced with #6 bars in fully grouted cells. The existing bond beams will not require enhancement provided that the above vertical reinforcement is added to the masonry walls as indicated.

According to the construction documents provided to us, all existing window jambs appear to be reinforced. Based on our experience, the masonry shear walls should have adequate strength to meet the ASCE 7-02 Standard for wind design provided that all the window jambs are reinforced and the above reinforcement enhancements are properly carried out.

Door and Window Systems – Building 7

The exterior windows and doors also require enhancement to meet the ASCE 7-02 Standard for wind design. All exterior windows and doors of Building 7 should be replaced to withstand the positive pressures of +45 psf and negative pressures of -60 psf. As an alternative, storm shutter systems can be installed in lieu of new window systems. Provide window, door, storm shutter, and frame systems that comply with performance requirements indicated, as demonstrated by testing manufacturer's assemblies in accordance with the International Building Code Test Standards ASTM E1886-05 dated 01-Jan-2005 "*Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials"* and ASTM E1996-05 dated 01-May-2005 *"Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes"*.

Rooftop Units – Building 6

There are many mechanical units sitting on the roof of the building. These units do not appear to be tied down sufficiently to the roof structure. During a hurricane, they may become wind borne missiles and destroy the roofing. All roof top mechanical units should be adequately tied down to the main structural members.

Foundation Systems – Building 7

According to the construction documents provided to us, all existing foundations appear to be adequate. Based on our experience, the spread footings should have adequate strength to meet the ASCE 7-02 Standard for wind design provided that they have been constructed in accordance with the construction documents.

COST ANALYSIS FOR WIND RETROFIT

Standards of Use

The cost estimates assume that the roof trusses in Buildings 6 & 7 have horizontal bridging every 10 feet of span in each joist. In the event that such bridging is not present as described in this report, additional costs can be expected.

The cost estimates include incidental costs such as grounds repair (Sitework), the temporary relocation of fixtures, furnishings and equipment inside the buildings (FF&E), structural design (Design), and construction engineering and inspection (CE&I). Cost savings of 10% and 13% for Buildings 6 & 7, respectfully could be saved if all the proposed work for each building is performed under single contracts.

Roof Envelope System – Building 6

The roof framing work would be as follows: Remove the existing roofing system. Haul away and dispose of unusable material. Properly secure roof deck and replace roof membrane and insulation. From within the building, modify the 20K5 joists as recommended.

Estimated roof envelope retrofit cost: $459,000

Wall System – Building 6

The wall system work would be as follows: Excavate around perimeter foundation to gain access. Open walls at specific locations for placement of vertical reinforcement. Place additional vertical reinforcement as indicated. Install temporary concrete forms and grout newly reinforced block walls. Strip forms and repair wall finishes.

Estimated wall system retrofit cost: $567,000

Door and Window Systems – Building 6

The door and window systems work would be as follows: Remove the existing 4 doors and replace with new hurricane resistant doors. Install new hurricane shutters on the existing 19 windows.

Estimated door and window systems retrofit cost: $137,000

Rooftop Units – Building 6

The rooftop units work would be as follows: Reattach the units to sufficiently withstand the design wind speeds indicated in this report. The cost estimate for this work is based on the square footage of the roof area.

Estimated rooftop units retrofit cost: $18,000

Foundation Systems – Building 6

None required except that which is required to retrofit the wall system.

Roof Envelope System – Building 7

The roof framing work would be as follows: From within the building, modify the 18K3 joists as recommended.

Estimated roof system retrofit cost: $148,000

Wall System – Building 7

The wall system work would be as follows: Excavate around perimeter foundation to gain access. Open walls at specific locations for placement of vertical reinforcement. Place additional vertical reinforcement as indicated. Install temporary concrete forms and grout newly reinforced block walls. Strip forms and repair wall finishes.

Estimated wall system retrofit cost: $564,000

Door and Window Systems – Building 7

The door and window systems work would be as follows: Remove the existing 2 doors and replace with new hurricane resistant doors. Install new hurricane shutters on the existing 10 windows.

Estimated door and window systems retrofit cost: $120,000

Rooftop Units – Building 7

The rooftop units work would be as follows: Reattach the units to sufficiently withstand the design wind speeds indicated in this report. The cost estimate for this work is based on the square footage of the roof area.

Estimated rooftop units retrofit cost: $18,000

Foundation Systems – Building 7

None required except that which is required to retrofit the wall system.

RECOMMENDATIONS AND CONCLUSIONS

This section presents the conclusions and recommendations from this portion of the HMTAP Task Order HSFEHQ-06-J-007.

Recommendations Summary for Building 6

- Reattachment of the roof deck system and re-sealing the roof
- Modification of 20K5 joists
- Secure rooftop units
- The addition of storm shutters and replacement of existing doors
- Addition of masonry wall reinforcement to all perimeter and interior load-bearing walls

Recommendations Summary for Building 7

- Modification of 18K3 joists
- Secure rooftop units
- The addition of storm shutters and replacement of existing doors
- Addition of masonry wall reinforcement to all perimeter and interior load-bearing walls

Conclusions

It is our professional opinion that once the above recommendations have been carried out to Buildings 6 & 7 at Harrison Central High School, the buildings will meet the requirements for wind loading indicated in the ASCE 7-02 Design Standard.

REFERENCES

1. http://www.ncdc.noaa.gov/oa/climate/research/2005/katrina.html, Summary of Hurricane Katrina, National Climatic Data Center, Last updated September 1, 2005
2. Cost Data, 2006 RS Means Book
3. Structural References, ASCE 7-02 Standard, Minimum Design Loads for Buildings and Other Structures
4. ASTM E1886-05, dated 01-Jan-2005, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*
5. ASTM E1996-05, dated 01-May-2005, *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*

LIST OF ACRONYMS

ASCE	American Society of Civil Engineers
CMU	Concrete Masonry Unit
DHS	Department of Homeland Security
EIFS	Exterior Insulating Finishing System
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HMGP	Hazard Mitigation Grant Program
HMTAP	Hazard Mitigation Technical Assistance Program
HUD	U.S. Department of Housing and Urban Development
JFO	Joint Field Office
MAT	Mitigation Assessment Team
mb	Millibars
mph	Miles per Hour
NAVD 88	North American Vertical Datum of 1988
CSI	Construction Specifications Institute

APPENDICES

Appendix A: Project Team

<u>Task Manager</u>
Ranko Pudar, P.E. – URS, Project Manager, Engineer
Leland Hennington, P.E. – URS, Field Manager, Engineer

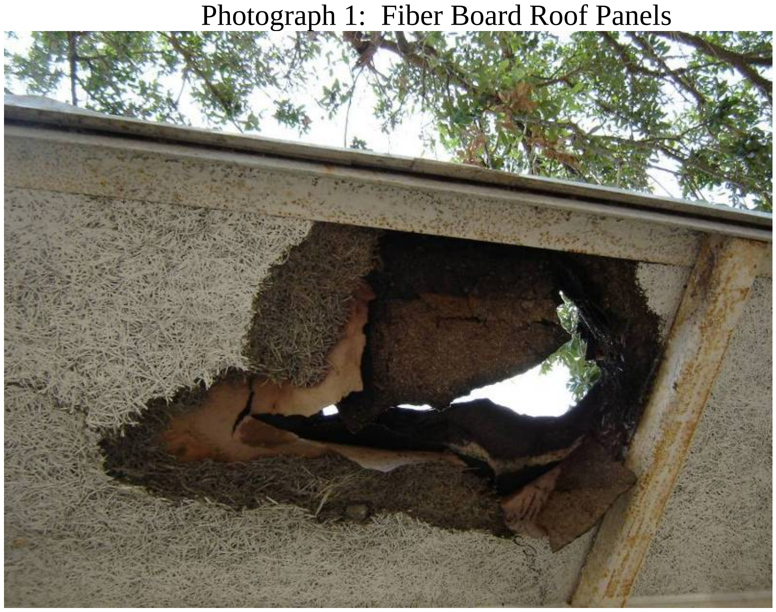
<u>Field Team 1</u>
Robert Gardner, CBO, AICP – PBS&J, Senior Planner
Mary Shaw, PhD, CFM, AICP – URS, Grant Writer Specialist
Mike Woods, P.E. – URS, Structural Engineer

<u>Task Order Advisors</u>
Dale Leaman, P.E. – URS, Senior Engineer
Scott Tezak, P.E. – URS, Structural Engineer

<u>Supplemental Team</u>
William Coulbourne, P.E. – URS, Structural Engineer
Doug Ramirez, E.I., M.S. – PBS&J, Structural Engineer
Roberto Archila, P.E. – PBS&J, Structural Engineer

Appendix B: Photographs

Photograph 1: Fiber Board Roof Panels



Photograph 2: Example of Moisture-Compromised Fiber Board Roof Panels

Appendix C: Figures

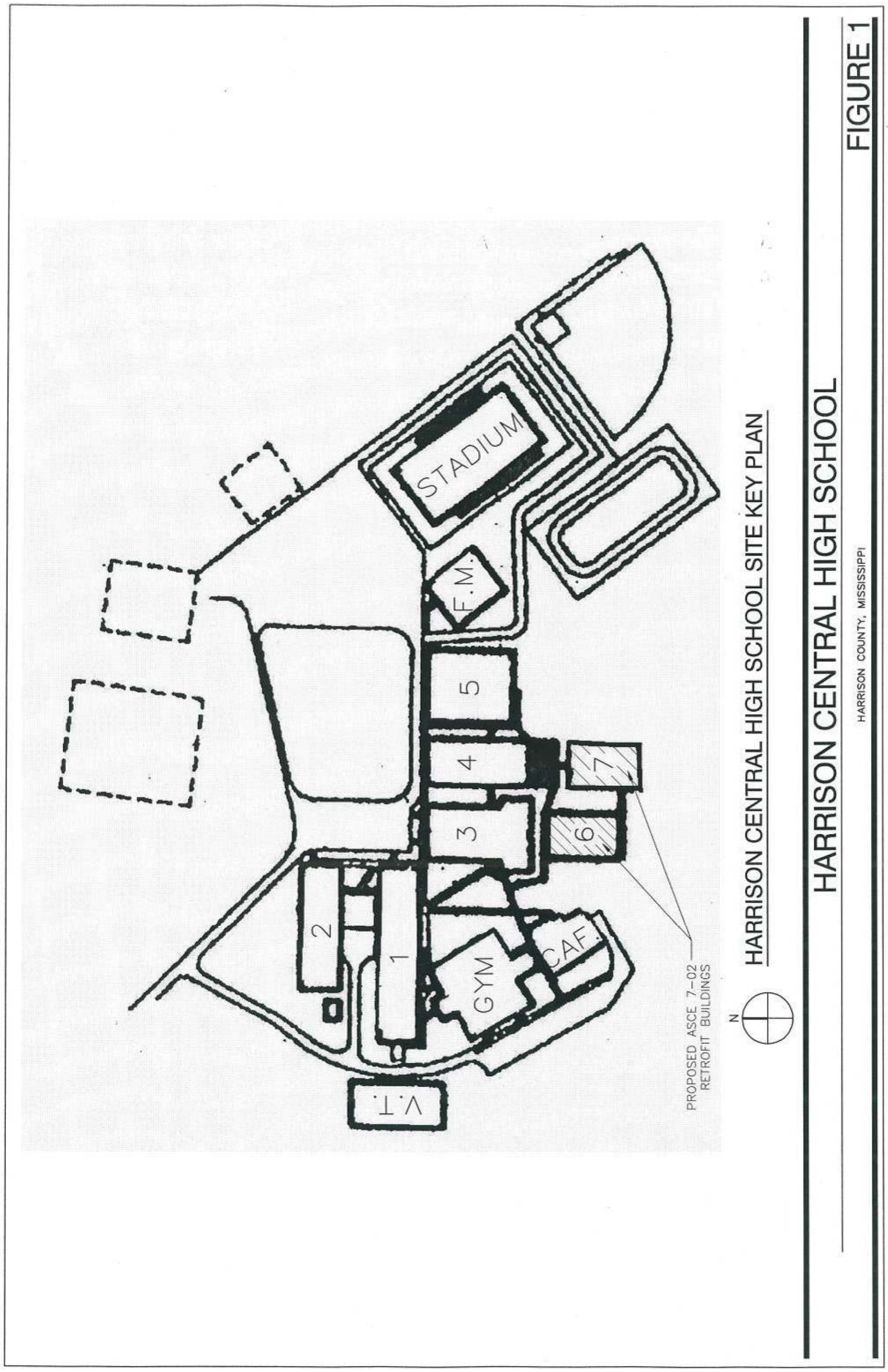


FIGURE 1

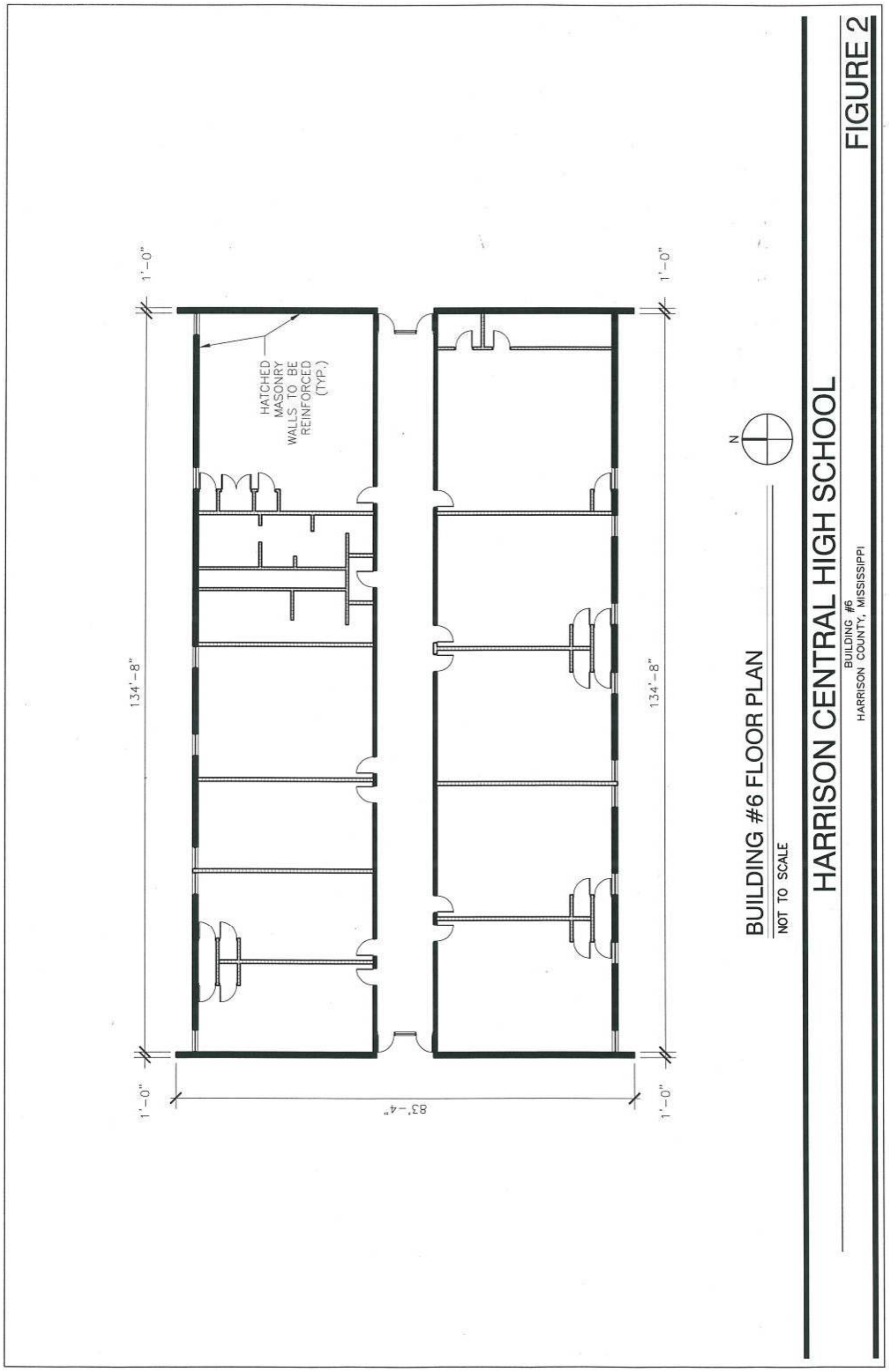


FIGURE 2
HARRISON CENTRAL HIGH SCHOOL
BUILDING #6
HARRISON COUNTY, MISSISSIPPI
BUILDING #6 FLOOR PLAN
NOT TO SCALE
N
HATCHED MASONRY WALLS TO BE REINFORCED (TYP.)
1'-0"
134'-8"
1'-0"
1'-0"
134'-8"
1'-0"
83'-4"

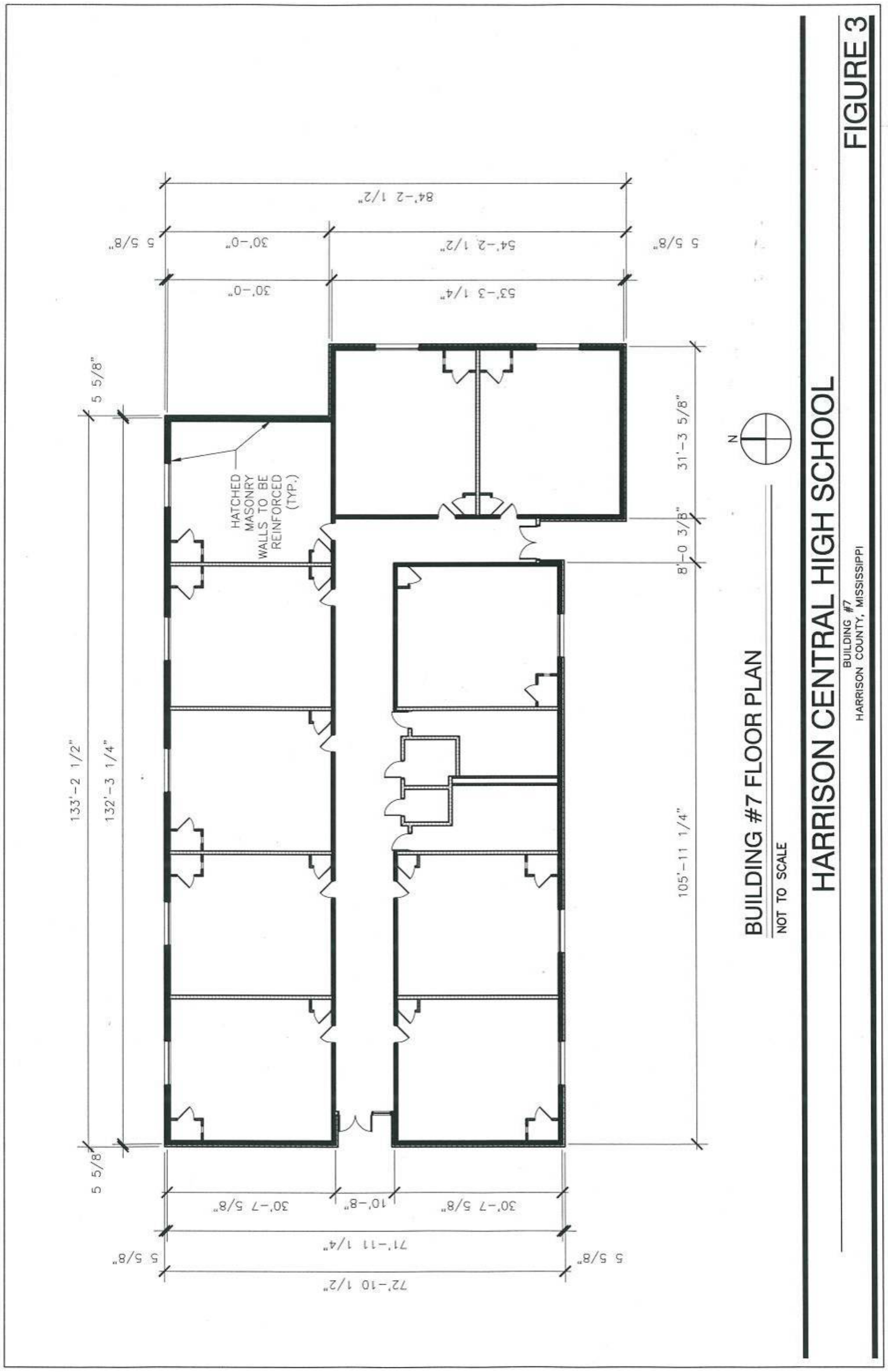
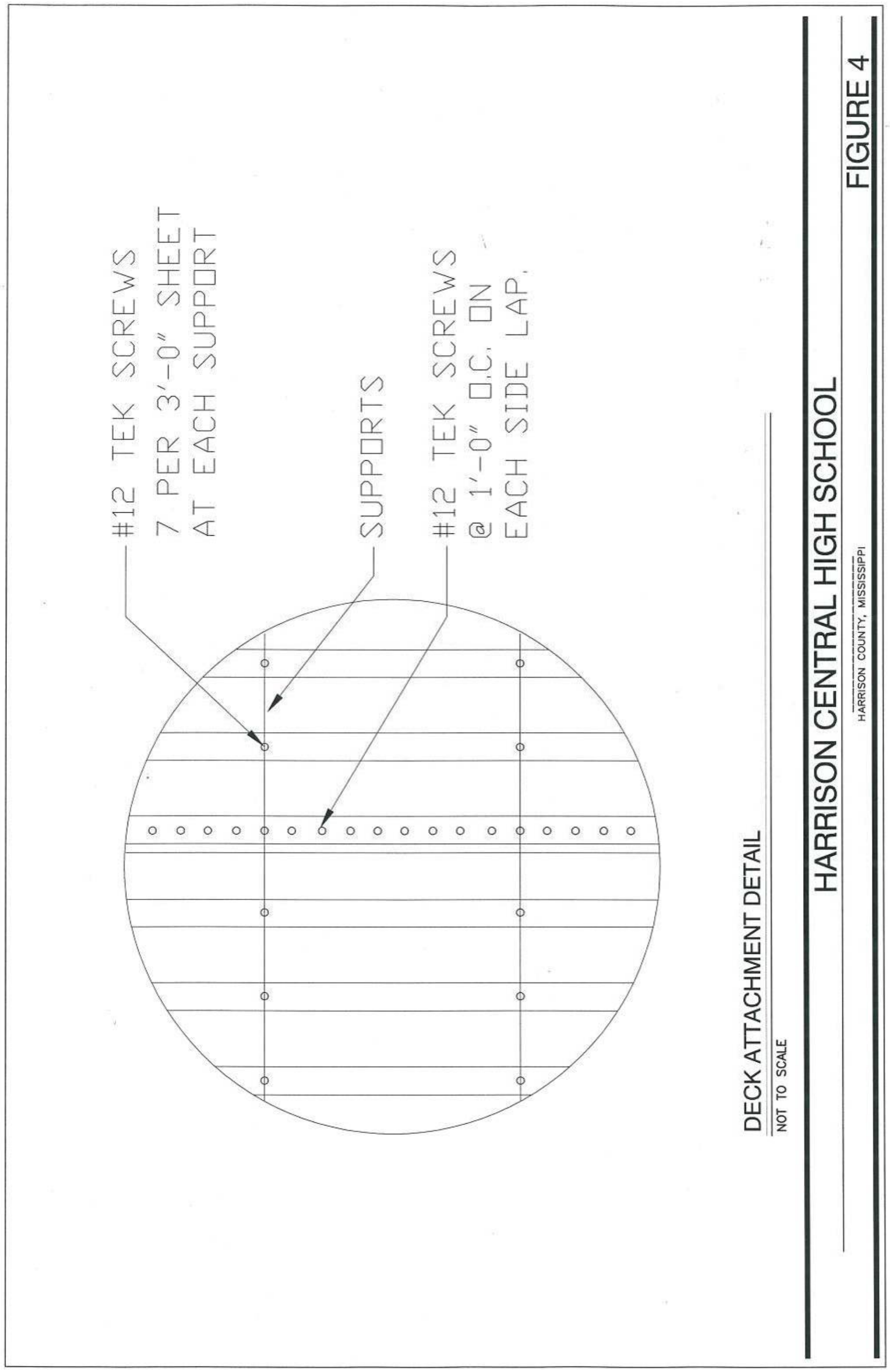
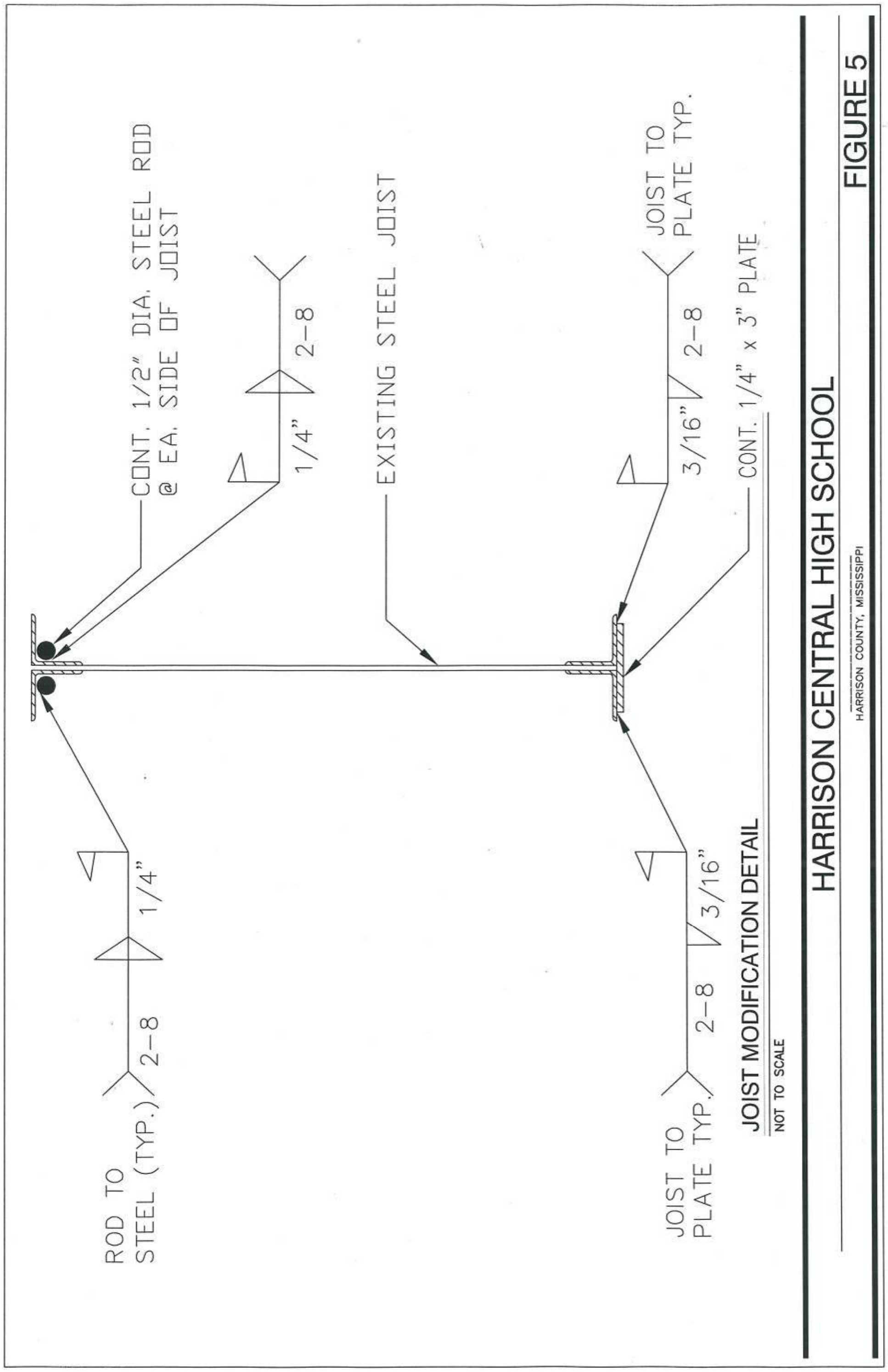


FIGURE 3
HARRISON CENTRAL HIGH SCHOOL
BUILDING #7
HARRISON COUNTY, MISSISSIPPI
BUILDING #7 FLOOR PLAN
NOT TO SCALE
HATCHED MASONRY WALLS TO BE REINFORCED (TYP.)
N
84'-2 1/2"
5 5/8"
30'-0"
54'-2 1/2"
53'-3 1/4"
31'-3 5/8"
8'-0 3/8"
105'-11 1/4"
133'-2 1/2"
132'-3 1/4"
30'-7 5/8"
10'-8"
71'-11 1/4"
72'-10 1/2"


#12 TEK SCREWS
7 PER 3'-0" SHEET
AT EACH SUPPORT
SUPPORTS
#12 TEK SCREWS
@ 1'-0" O.C. ON
EACH SIDE LAP.
DECK ATTACHMENT DETAIL
NOT TO SCALE
HARRISON CENTRAL HIGH SCHOOL
HARRISON COUNTY, MISSISSIPPI
FIGURE 4


CONT. 1/2" DIA. STEEL ROD
@ EA. SIDE OF JOIST
1/4"
2-8
EXISTING STEEL JOIST
JOIST TO
PLATE TYP.
3/16"
2-8
CONT. 1/4" x 3" PLATE
ROD TO
STEEL (TYP.)
2-8
1/4"
JOIST TO
PLATE TYP.
2-8
3/16"
JOIST MODIFICATION DETAIL
NOT TO SCALE
HARRISON CENTRAL HIGH SCHOOL
HARRISON COUNTY, MISSISSIPPI
FIGURE 5

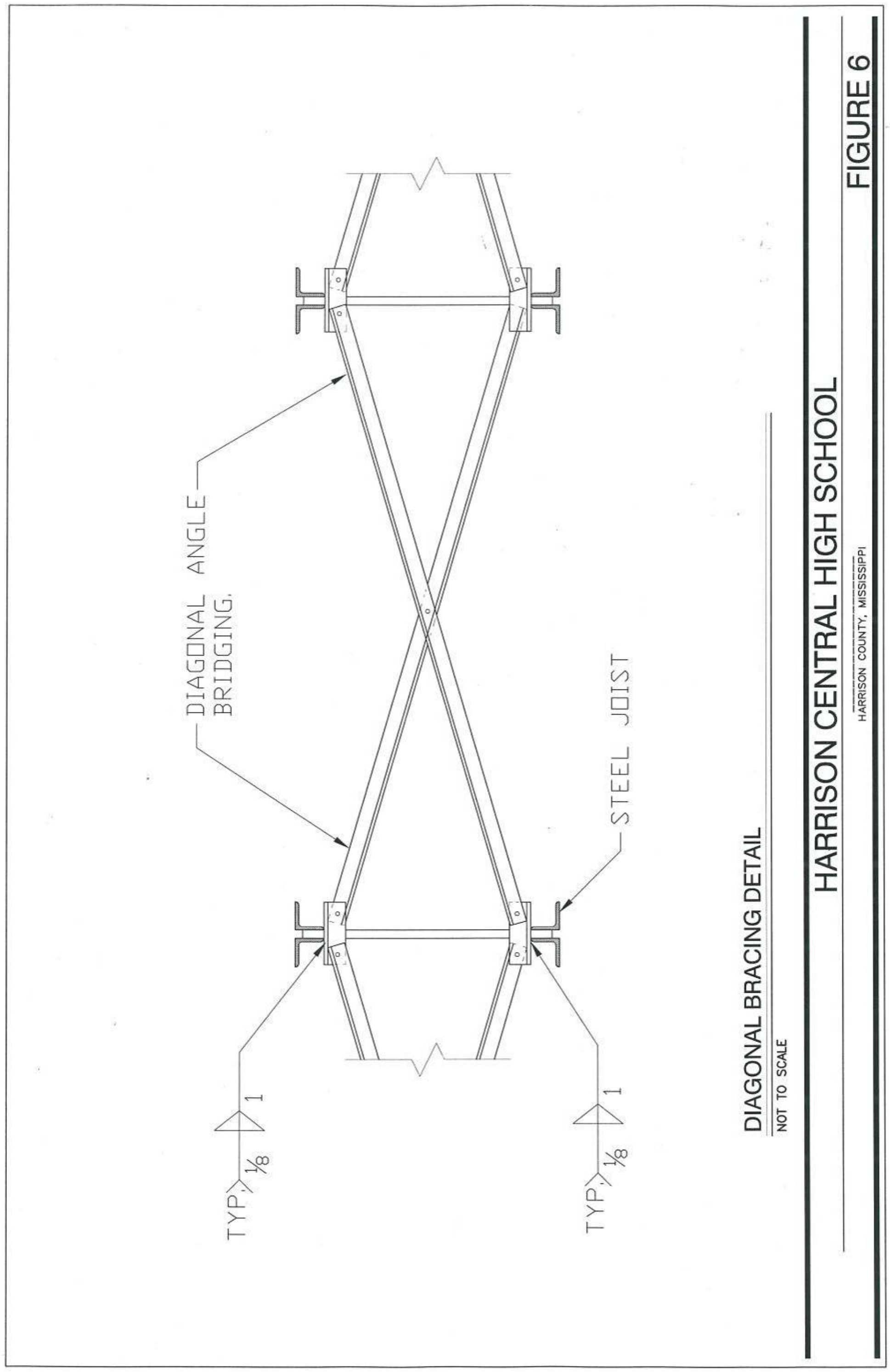
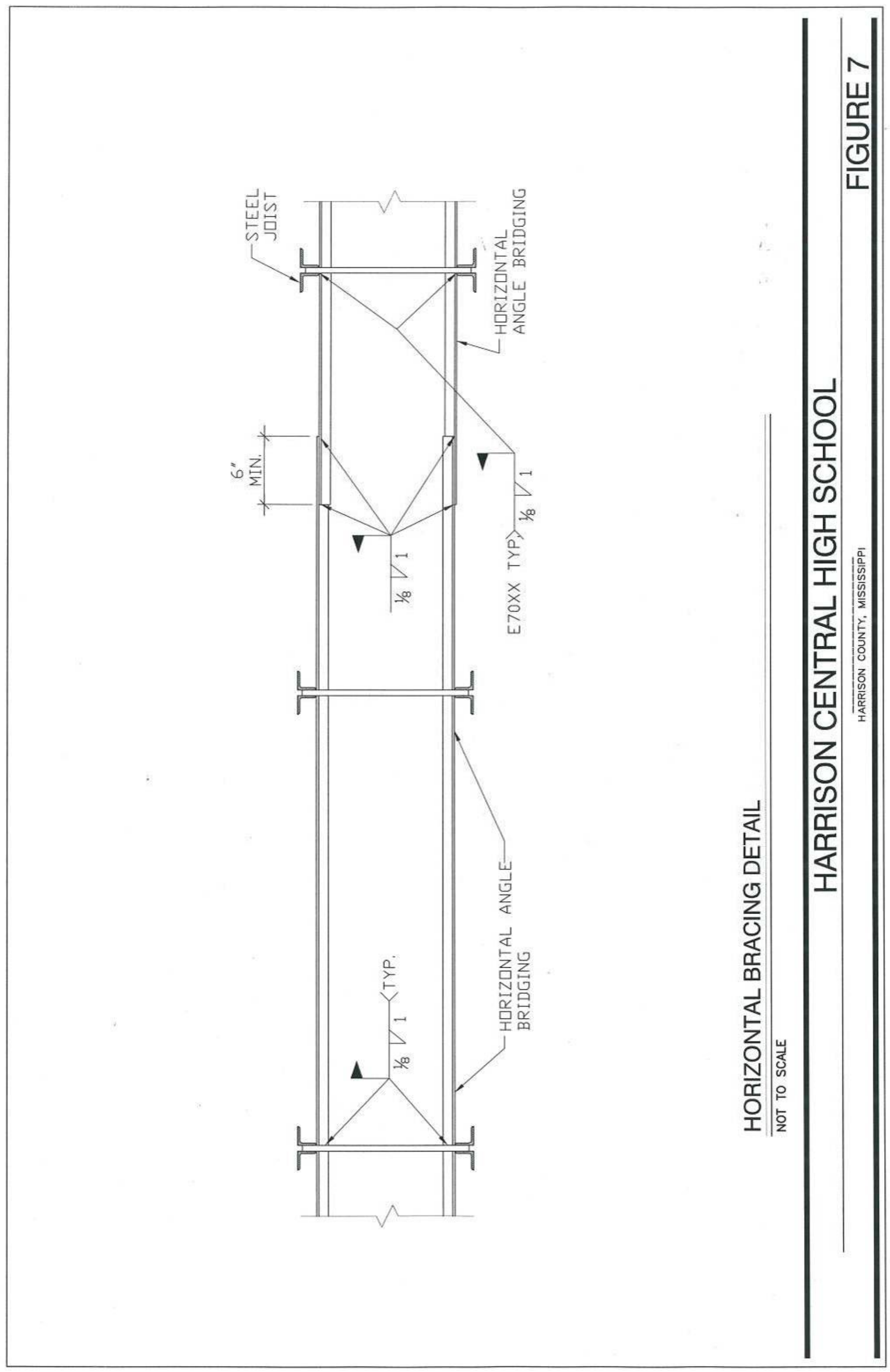


FIGURE 6
HARRISON CENTRAL HIGH SCHOOL
HARRISON COUNTY, MISSISSIPPI
DIAGONAL BRACING DETAIL
NOT TO SCALE
DIAGONAL ANGLE BRIDGING.
STEEL JOIST
TYP. 1/8 1
TYP. 1/8 1


STEEL JOIST
HORIZONTAL ANGLE BRIDGING
6" MIN.
1/8 1
E70XX TYP. 1/8 1
TYP.
HORIZONTAL ANGLE BRIDGING
HORIZONTAL BRACING DETAIL
NOT TO SCALE
HARRISON CENTRAL HIGH SCHOOL
HARRISON COUNTY, MISSISSIPPI
FIGURE 7