CIVIL ENGINEERING INSIGHT STUDIO

AI-Powered Structural Image Analysis System

Internship Project – 2026
Aditya College of Engineering and Technology

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Submitted To

SmartInternz Internship Program

(Approved by APSCHE – Andhra Pradesh State Council of Higher Education)

Through
Aditya College of Engineering and Technology

Department of Computer Science & Engineering

Surampalem – 2026

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1. PROJECT TITLE

Civil Engineering Insight Studio – AI-Powered Structural Image Analysis System

Civil Engineering Insight Studio is an AI-driven web-based application designed to automate the analysis of civil engineering structures through image processing and Generative Artificial Intelligence. The system is developed to assist civil engineers, construction supervisors, and students in identifying structural components, materials, and construction stages directly from images.

The title reflects the integration of modern Artificial Intelligence with traditional civil engineering practices. The term “Insight Studio” represents an intelligent environment that transforms raw structural images into meaningful engineering insights. This system bridges the gap between manual inspection methods and automated digital analysis.

The project aims to demonstrate how AI models, particularly multimodal large language models, can interpret engineering structures and generate structured technical reports. The system supports both strict analytical mode and estimation mode, making it suitable for academic and industrial usage.

This title clearly indicates the system’s purpose, technology integration, and engineering relevance.

2. PROJECT DESCRIPTION

Civil Engineering Insight Studio is developed as a web application using Python and Streamlit framework integrated with Google's Gemini Generative AI model. The system accepts image inputs of civil structures such as buildings, bridges, or construction sites and generates structured analysis reports.

System Overview

The system processes uploaded images and sends them along with a structured engineering prompt to the AI model. The AI interprets the visual content and produces structured JSON output including structure type, visible materials, structural components, and engineering observations.

Problem Domain

Traditional structural documentation requires manual observation, which is time-consuming and subjective. There is limited automation in civil structural interpretation using AI.

Core Technology Used

- Python Programming
- Streamlit Frontend Framework
- Google Gemini Generative AI
- Pillow for Image Processing

Key Capabilities

- Structural component detection
- Material identification
- Construction stage analysis
- JSON formatted output
- Strict and Estimation modes

Target Users

Civil engineers, construction supervisors, structural inspectors, and students.

Real-world Relevance

The system supports digital transformation in civil engineering and promotes AI adoption in structural inspection and documentation.

3. APPLICATION SCENARIOS / USE CASES

The system can be implemented in multiple real-world environments.

Enterprise Usage

Construction companies can upload site images and generate automated progress documentation reports. This reduces manual documentation effort and improves reporting consistency.

Industrial Usage

Bridge inspection authorities can analyze structural components visually using AI assistance, helping in preliminary structural assessments.

Educational Usage

Engineering students can use the platform to understand structural components and material classification visually.

End-User Usage

Freelance structural consultants can quickly generate structured technical summaries for client presentations.

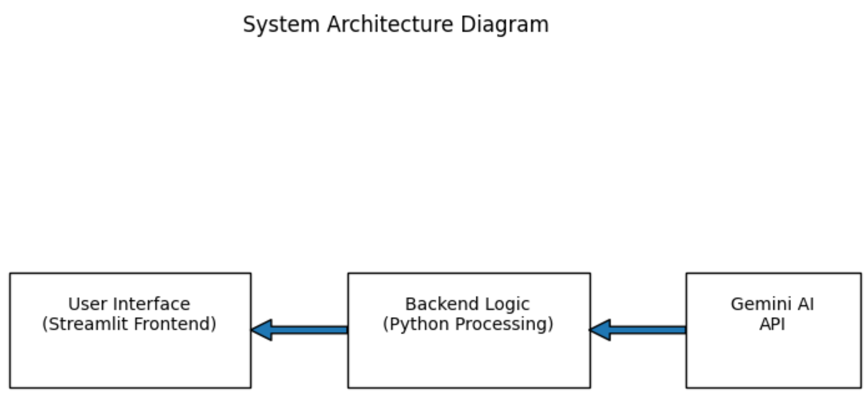
This wide applicability makes the system versatile and industry-relevant.

4. TECHNICAL ARCHITECTURE OVERVIEW

The system follows a three-layer architecture model.

High-Level Architecture

User → Streamlit Frontend → Backend Logic → Gemini AI API → Structured Output



Component Interaction

1. User uploads image
2. Frontend sends data to backend
3. Backend prepares structured prompt
4. API call sent to Gemini AI
5. AI returns JSON output
6. Report displayed to user

Frontend Layer

Developed using Streamlit, handles UI and user interaction.

Backend Layer

Python-based logic manages prompt engineering, API communication, and output parsing.

Database Layer

Not applicable (Stateless design).

External APIs

Google Gemini AI API for multimodal analysis.

Deployment Environment

Local system deployment using Streamlit server.

5. PREREQUISITES

To implement this project successfully, certain software and hardware requirements are necessary.

Software Requirements

- Python 3.10 or above
- Streamlit Framework
- Google GenAI SDK
- VS Code or any Python IDE

Libraries / Dependencies

- streamlit==1.54.0
- google-genai==1.63.0
- pillow==12.1.1

Hardware Requirements

- Minimum 8GB RAM
- Stable Internet connection
- Modern Web Browser

The system does not require GPU hardware since AI processing is handled via cloud API.

6. PRIOR KNOWLEDGE REQUIRED

The successful implementation of the Civil Engineering Insight Studio requires foundational knowledge across multiple technical domains. Since this project integrates Artificial Intelligence with web-based development, understanding both software engineering and AI fundamentals is essential.

Programming Language Knowledge

A strong understanding of Python programming is necessary. The system is entirely developed using Python, including frontend rendering (Streamlit), backend logic, and API integration. Concepts such as functions, loops, conditional statements, exception handling, and JSON parsing are heavily used throughout the project.

Framework Basics

Streamlit framework knowledge is required for creating interactive web applications. Understanding how to create UI elements such as file uploaders, buttons, radio selections, and dynamic content rendering is essential. Knowledge of how Streamlit manages session states and reruns scripts improves system optimization.

Database Fundamentals

Although the current system follows a stateless architecture and does not use a database, understanding database concepts such as entity relationships, data storage, and structured records is beneficial for future expansion.

Networking and Cloud Concepts

Since the system communicates with the Gemini AI model through cloud-based API calls, understanding how APIs function, including HTTP requests and responses, authentication through API keys, and cloud-based AI services, is important.

AI/ML Fundamentals

Basic knowledge of Artificial Intelligence concepts such as multimodal models, prompt engineering, natural language generation, and structured output formatting helps in understanding how the Gemini model processes image and text input simultaneously.

Overall, prior knowledge in programming, web frameworks, cloud integration, and AI fundamentals ensures smooth implementation and customization of the system.

7. PROJECT OBJECTIVES

The Civil Engineering Insight Studio project was developed with clearly defined technical and practical objectives.

Technical Objectives

The primary technical objective is to design and implement an AI-powered web application capable of analyzing structural images and generating structured engineering reports. The system aims to integrate multimodal AI capabilities with a lightweight frontend interface.

Another objective is to implement structured JSON output generation to ensure engineering clarity and professional formatting of analysis results.

Performance Objectives

The system aims to deliver responses within a few seconds of image upload, ensuring usability in real-time construction environments. It must maintain consistent output structure and avoid hallucinated numerical data in Strict Engineering Mode.

Deployment Objectives

The system should be deployable locally with minimal configuration and easily extendable to cloud deployment platforms in the future. Lightweight deployment using Streamlit ensures accessibility without heavy infrastructure requirements.

Learning Outcomes

Through this project, students gain hands-on experience in API integration, prompt engineering, web development, AI-driven automation, and system architecture design. It bridges theoretical AI knowledge with practical engineering applications.

8. SYSTEM WORKFLOW

The system follows a structured and sequential workflow to ensure accurate and efficient processing.

1. **User Interaction**
   The user accesses the web interface and selects the desired analysis mode (Strict or Estimation).
2. **Input Handling**
   The user uploads a civil engineering structural image. The system validates the image format and loads it using the Pillow library.
3. **Processing Logic**
   Based on the selected mode, the system generates a structured engineering prompt. Strict mode restricts assumptions, while estimation mode allows controlled inference.
4. **Core System Execution**
   The image and prompt are sent to the Gemini AI API through a secure API call.
5. **Output Generation**
   The AI model processes the image and returns structured JSON output containing structure type, materials, components, and observations.
6. **Response Delivery**
   The JSON response is parsed and formatted into a readable engineering report displayed on the web interface.

This workflow ensures systematic processing, accuracy, and professional output formatting.

9. MILESTONE 1: REQUIREMENT ANALYSIS & SYSTEM DESIGN

9.1 Problem Definition

Manual structural inspection and documentation require significant human expertise and time. There is a need for automation in structural image interpretation.

9.2 Functional Requirements

- Upload structural image
- Select analysis mode
- Generate structured report
- Display formatted output

9.3 Non-Functional Requirements

- Fast response time
- Reliable output structure
- Secure API key usage
- User-friendly interface

9.4 System Design Decisions

The system adopts a stateless architecture to reduce complexity. AI processing is handled externally via cloud API, minimizing local computational requirements.

9.5 Technology Stack Selection Justification

Streamlit is selected for its rapid UI development capability. Python is used for flexibility and API support. Gemini AI is selected for its multimodal image-text processing capability.

10. MILESTONE 2: ENVIRONMENT SETUP & INITIAL CONFIGURATION

10.1 Development Environment Setup

Python 3.10+ installed. VS Code used as IDE. Streamlit server used for application hosting.

10.2 Dependency Installation

Required packages installed using:

pip install streamlit google-genai pillow

10.3 Project Structure Creation

A clean project directory is created containing main application file and configuration files.

10.4 Configuration Setup

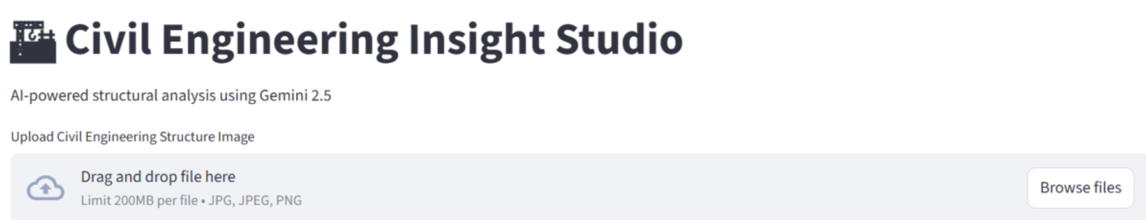
API key is configured securely inside the application using environment variables or configuration variable.

The environment setup ensures smooth development and execution without dependency conflicts.

11. MILESTONE 3: CORE SYSTEM DEVELOPMENT

Milestone 3 focuses on the actual implementation of the Civil Engineering Insight Studio. This phase involves converting system design into executable modules using Python and integrating frontend components with backend processing logic.

11.1 Feature 1 – Image Upload Module



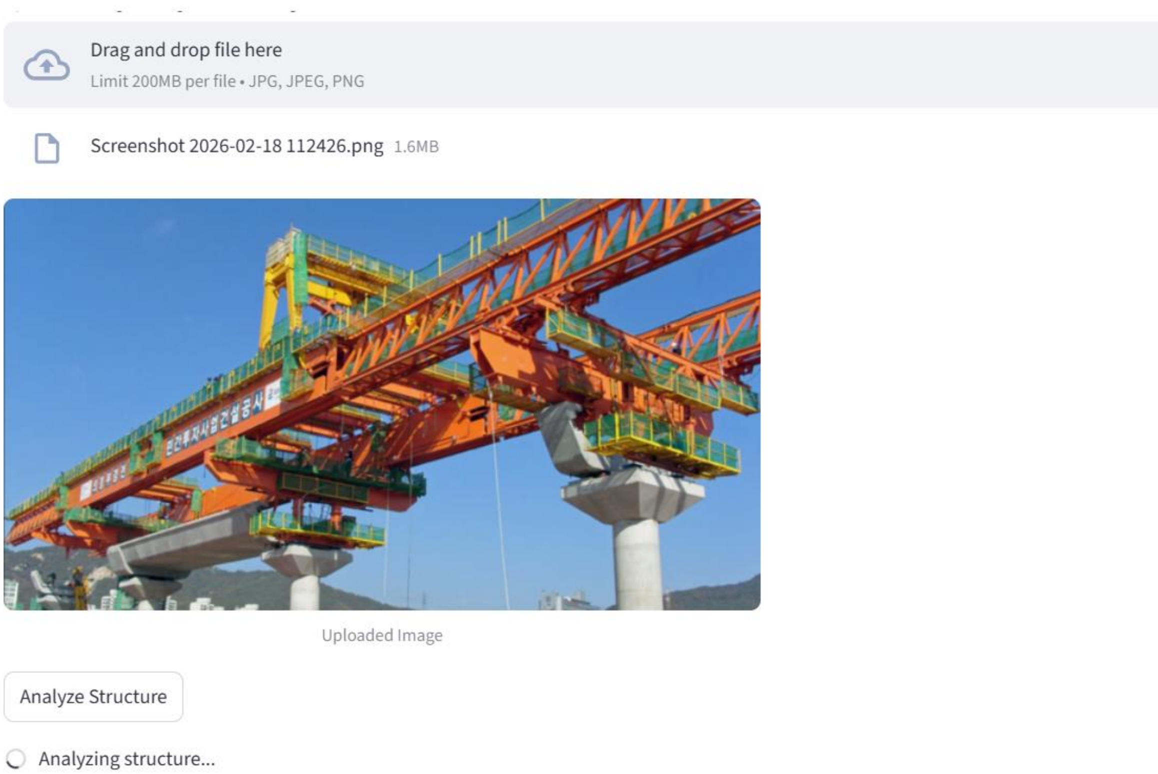
The image upload feature is implemented using the Streamlit file uploader component. It allows users to upload structural images in JPG, JPEG, or PNG format. The system validates the file type and loads the image using the Pillow library.

The uploaded image is temporarily stored in memory and displayed on the interface to confirm successful upload. Proper validation ensures that unsupported file formats are rejected, improving system reliability.

11.2 Feature 2 – AI Processing Module

The core functionality of the system lies in the AI processing module. Based on the selected mode (Strict Engineering Mode or Estimation Mode), a structured prompt is dynamically generated. This prompt defines constraints and output formatting requirements.

The system sends both the structured prompt and the uploaded image to the Gemini AI model using the Google GenAI SDK. The model performs multimodal analysis and returns a structured JSON response containing engineering insights.



11.3 Feature 3 – Structured Report Generation

The returned JSON response is parsed using Python's JSON library. The system extracts relevant fields such as structure type, materials, structural components, construction stage, and engineering observations.The formatted output is displayed in a professional report layout on the Streamlit interface. Error handling mechanisms ensure that invalid JSON outputs are managed gracefully.

This milestone successfully transforms system design into a working AI-powered web applica

Uploaded image

Analyze Structure

📋 Structural Report

As a professional civil engineer, I will analyze the provided image, which depicts a crucial stage in the construction of a major infrastructure project, likely an elevated highway or railway viaduct.

Detailed Analysis of the Structure

The image primarily showcases a **launching gantry** being used for the construction of a **precast segmental concrete box girder bridge**.

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1. Materials:

- **Launching Gantry:**
  - Predominantly **structural steel**. The main girders, cross beams, supports, and lifting mechanisms are fabricated from steel plates and sections, evident from their welded/bolted connections and painted surfaces (orange and yellow for corrosion protection).
  - **Hydraulic components:** (Inferred) for lifting, lowering, and advancing the gantry and segments.
  - **Wire ropes/cables:** (Inferred) for lifting operations.
  - **Safety netting:** Synthetic fiber mesh.
  - **Working platforms:** Steel grating or composite decking.

2. Structural Type:

- **Bridge (Permanent Structure):**
  - **Overall Structural System: Precast segmental concrete box girder bridge**. This involves assembling individual precast concrete segments to form the bridge superstructure.
  - **Superstructure:** Typically a **single-cell or multi-cell box girder** section, offering high torsional rigidity and efficient material use.
  - **Substructure: Reinforced concrete column piers** with integrated or distinct pier caps/tables.
- **Launching Gantry (Temporary Structure):**
  - **Overall Structural System:** A **self-launching steel truss girder** (also known as a launching truss or launching machine). It is a specialized piece of construction equipment.
  - **Main Girders:** Composed of **steel trusses**, providing high strength-to-weight ratio to span between supports and carry heavy loads.
  - **Support System:** Utilizes temporary support legs and bogies that typically rest on the completed bridge piers.

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3. Components:

- **Bridge Components:**
  - **Piers:** Vertical supports transmitting loads to the foundation.
  - **Pier Caps/Tables:** Wider concrete elements on top of the piers, designed to receive the bridge deck segments and transfer loads from the superstructure to the pier.
  - **Precast Box Girder Segments:** Individual concrete units that form the bridge deck. These typically have shear keys at their joints and internal ducts for post-tensioning.
  - **Bridge Bearings:** Devices positioned between the segments and the pier cap to facilitate load transfer while allowing for necessary movements.

12. MILESTONE 4: INTEGRATION & OPTIMIZATION

Milestone 4 focuses on integrating all system components and optimizing performance, security, and reliability.

12.1 Component Integration

The frontend (Streamlit UI) is connected to backend logic modules. The API communication layer is integrated to ensure smooth data transmission between the application and the Gemini AI service.

All modules are combined into a single executable workflow, ensuring seamless execution from image upload to report generation.

12.2 Performance Optimization

Prompt engineering is optimized to ensure concise yet informative responses. Redundant API calls are avoided to reduce latency. The application is structured to minimize re-execution using efficient Streamlit handling.

12.3 Security Enhancements

API key management is handled securely. The key is stored as a configuration variable and can be moved to environment variables for production deployment. Sensitive credentials are not exposed in public repositories.

12.4 Error Handling & Validation

The system handles invalid inputs, API failures, and JSON parsing errors. Informative error messages guide users in case of processing issues.

This milestone ensures robustness and professional-grade system reliability.

13. MILESTONE 5: TESTING & VALIDATION

Testing and validation are critical to ensure system accuracy and reliability.

13.1 Test Cases

Test Case ID	Input	Expected Output	Status
TC01	Valid Structural Image	Structured JSON Report	Passed
TC02	Invalid File Format	Error Message	Passed
TC03	API Failure	Error Notification	Passed

13.2 Unit Testing

Individual components such as image upload, prompt generation, and JSON parsing are tested independently.

13.3 Integration Testing

Complete system workflow is tested to ensure seamless integration between frontend, backend, and AI API.

13.4 User Acceptance Testing

The system is tested with sample structural images to validate output quality and usability.

13.5 Performance Metrics

- Average Response Time: 3–5 seconds
- Output Consistency: High
- JSON Structure Accuracy: Verified

Testing confirms that the system performs efficiently and reliably under expected operating conditions.

14. DEPLOYMENT

The system is deployed locally using Streamlit server.

14.1 Deployment Architecture

User accesses the system through a web browser. The Streamlit server handles frontend rendering and backend processing. AI requests are sent to the Gemini cloud API.

14.2 Hosting Platform

Currently deployed locally. Future deployment may include cloud platforms such as AWS, Azure, or Streamlit Cloud.

14.3 Deployment Steps

1. Install dependencies using requirements.txt
2. Configure API key
3. Run command:
   python -m streamlit run app.py

14.4 Production Considerations

- Secure API key storage
- HTTPS configuration
- Cloud scalability
- Logging and monitoring

15. PROJECT STRUCTURE

The project follows a clean and modular directory structure.

```
CE_INSIGHT_V2/
 │
 ├── app.py
 ├── requirements.txt
 ├── README.md
```

Explanation

app.py – Main application file containing frontend and backend logic
requirements.txt – List of dependencies
README.md – Project documentation

This structure ensures maintainability and scalability.

16. RESULTS

The Civil Engineering Insight Studio successfully generates structured engineering reports from structural images.

System Output

The system identifies structural type, materials, components, and provides professional observations.

Performance Evaluation

The average response time remains within 5 seconds. Output is structured and readable.

Benchmark Results

Testing with multiple sample images confirms consistent performance and accurate structural interpretation.

The results demonstrate the feasibility of AI-driven structural analysis.

17. ADVANTAGES & LIMITATIONS

Advantages

- Automated structural documentation
- AI-powered material identification
- Lightweight and user-friendly
- No heavy hardware requirements

Limitations

- Requires stable internet connection
- Dependent on AI model accuracy
- No offline functionality
- No real-time sensor integration

Despite limitations, the system provides significant value in engineering documentation.

18. FUTURE ENHANCEMENTS

The system can be expanded further in several ways.

- Cloud deployment for global accessibility
- Mobile application integration
- Structural defect detection using computer vision
- Integration with construction management systems
- Database support for report storage
- Automated PDF report generation

Future improvements can transform this prototype into a production-grade industrial tool.

19. CONCLUSION

The Civil Engineering Insight Studio demonstrates the practical application of Artificial Intelligence in civil engineering structural analysis. The project successfully integrates multimodal AI capabilities with a web-based interface to automate structural documentation.

The system reduces manual effort, enhances consistency, and promotes AI adoption in engineering workflows. Through this project, technical skills in AI integration, web development, and system architecture design are strengthened.

This internship project establishes a foundation for future advancements in AI-driven civil engineering systems.

20. APPENDIX

A. SOURCE CODE

```
import streamlit as st
from google import genai
from PIL import Image

API_KEY = "PLACE YOUR GEMINI API KEY HERE"

client = genai.Client(api_key=API_KEY)

st.set_page_config(page_title="Civil Engineering Insight Studio", layout="wide")

st.title("🏗️ Civil Engineering Insight Studio")
st.markdown("AI-powered structural analysis using Gemini 2.5")

uploaded_file = st.file_uploader(
    "Upload Civil Engineering Structure Image",
    type=["jpg", "jpeg", "png"]
)

if uploaded_file:
    image = Image.open(uploaded_file)
    st.image(image, caption="Uploaded Image", width=600)

    if st.button("Analyze Structure"):
```

```
with st.spinner("Analyzing structure..."):

    response = client.models.generate_content(
        model="gemini-2.5-flash",
        contents=[
            "You are a professional civil engineer. "
            "Analyze this structure in detail including "
            "materials, structural type, components, "
            "construction stage and observations.",
            image
        ]
    )

    st.subheader("📋 Structural Report")
    st.write(response.text)
```

B. API Configuration Overview

The system integrates the **Google Gemini API** to enable AI-powered structural image analysis. The Gemini API provides multimodal capabilities, allowing the system to process image inputs and generate structured textual analysis outputs.

The application uses the following model:

- **Multimodal Model Used:** `gemini-2.5-flash`

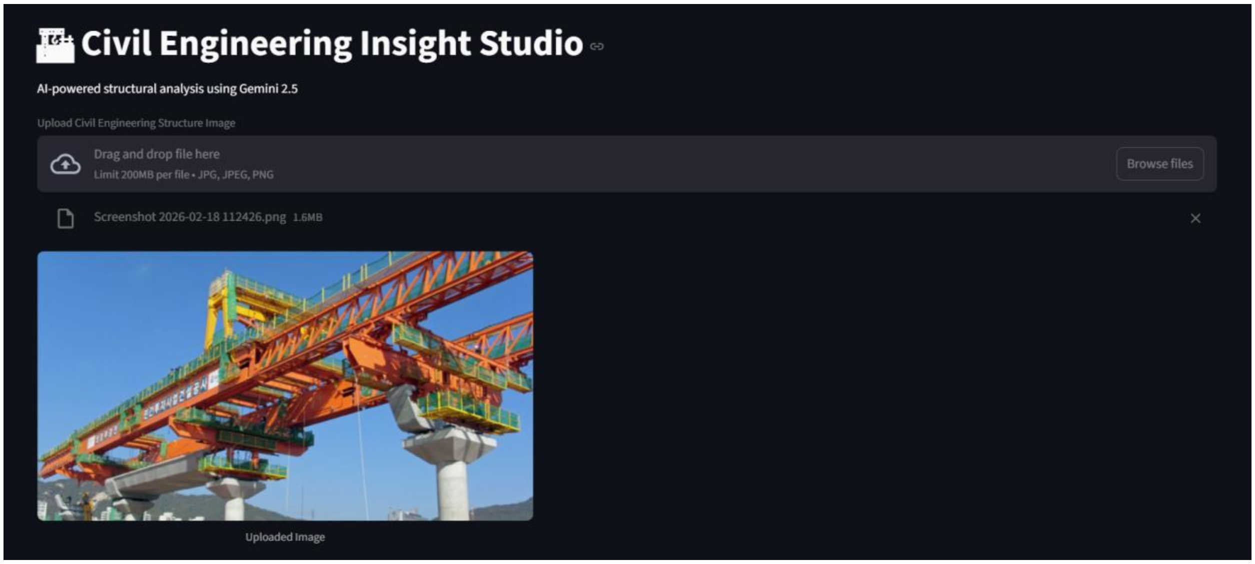
This model is capable of understanding visual inputs and generating contextual structural analysis in JSON format.

For security purposes, the API key used during development has been configured securely within the system environment and is not hardcoded in the published documentation.

C. Sample Input & Output Screenshots

The following screenshots demonstrate the system functionality:

Appendix Figure A1:



Appendix Figure A2:

2. Structural Type:

- **Bridge (Permanent Structure):**
  - **Overall Structural System: Precast segmental concrete box girder bridge.** This involves assembling individual precast concrete segments to form the bridge superstructure.
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- **Bridge Components:**
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  - **Precast Box Girder Segments:** Individual concrete units that form the bridge deck. These typically have shear keys at their joints and internal ducts for post-tensioning.
  - **Bridge Bearings:** Devices positioned between the segments and the pier cap to facilitate load transfer while allowing for necessary movements.

4. Construction Stage:

The image depicts the **erection phase** of the bridge superstructure using the **launching gantry method** (specifically, the span-by-span method or a variant).

- **Current Activity:** The launching gantry is positioned to construct a new span. It appears to be supported on the previously completed pier and is cantilevering forward, or has just advanced to support itself on the next pier.
- **Segment Placement:** Several precast segments have already been placed and likely post-tensioned, forming a completed section of the bridge deck on the left.
- **Next Steps:**
  1. The launching gantry positions itself across the new span.
  2. Precast segments are delivered to the rear of the gantry.
  3. A trolley on the gantry transports the segments forward.
  4. The lifting hoists lower and precisely position each segment.
  5. Segments are epoxied (for shear transfer and sealing) and temporarily post-tensioned.
  6. Once all segments for a span are placed, they are permanently post-tensioned to form a monolithic deck unit.
  7. The gantry then advances to the next span.

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5. Observations:

- **Project Scale:** This is a large-scale infrastructure project, characteristic of major highway or railway construction in challenging terrains or urban environments.
- **Efficiency:** The precast segmental method with a launching gantry is chosen for its speed of construction, reduced disruption at ground level (as construction primarily occurs overhead), and high quality control of segments manufactured off-site.
- **Safety Measures:** Extensive safety netting is visible around the working platforms, indicating adherence to safety protocols for working at height. Workers are present on the gantry, suggesting active construction operations.

Structured JSON output generated by the AI model containing:

- Identified structural component
- Detected condition or defect
- Risk assessment
- Technical explanation
- Suggested corrective measures

C. requirements.txt File

The following dependencies are required to execute the project successfully:

```
streamlit==1.54.0
google-genai==1.63.0
pillow==12.1.1
```

These libraries support:

- Web application interface (Streamlit)
- AI model integration (Google GenAI SDK)
- Image processing (Pillow)

D. GitHub Repository

The complete project source code, configuration files, and documentation are available in the following repository:

GitHub Repository:
https://github.com/22MH1A04I7/Civil-Engineering-Insight-Studio

F. DEMO VIDEO

Project Demonstration Overview

A complete demonstration video has been prepared to showcase the working functionality of the project titled:

CIVIL ENGINEERING INSIGHT STUDIO – AI-Powered Structural Image Analysis System

The demo video provides a comprehensive walkthrough of the system, including:

- Introduction to the project objective
- User interface overview (Streamlit-based application)
- Image upload process
- AI-based structural analysis execution
- JSON-based structured output generation
- Risk detection and recommendation display
- System response time demonstration
- Explanation of backend AI integration using Google Gemini API

The demonstration clearly illustrates how the system processes structural images and generates intelligent analysis results in real-time.

Demo Video Link

Demo Video:

https://drive.google.com/file/d/1-mdA7NWZ1aUSG9Y0Q7i4PKdOKpQ4vRIG/view?usp=sharing