# Secure Login & User Authentication System

## Personal Project Report

**Student Name:** 張睿恩
**Student ID:** 111590028
**Course:** Software Security and Reverse Engineering
**Live Demo:** https://ss.zre.tw/
**GitHub Repository:** https://github.com/HeavenManySugar/ss-personal-project

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## 1. Introduction

This project implements a secure user authentication system deployed on Cloudflare Workers, demonstrating modern security practices against common web vulnerabilities including SQL Injection, XSS, CSRF, and brute-force attacks.

**Key Features:** User registration with email verification • Secure login with account lockout • Multi-Factor Authentication (TOTP & Email) • OAuth integration (Google, GitHub) • Session management with CSRF protection • Admin panel

**Technology Stack:** Astro 5.16 (SSR) • Cloudflare Workers • D1 Database (SQLite) • PBKDF2-SHA256 (100K iterations) • TOTP (RFC 6238) • OAuth 2.0 (RFC 6749) • Resend API

### System Screenshots

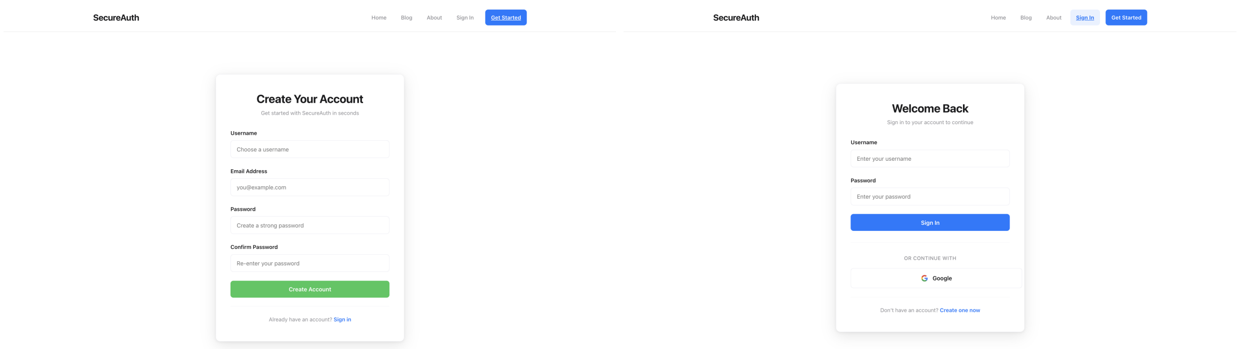
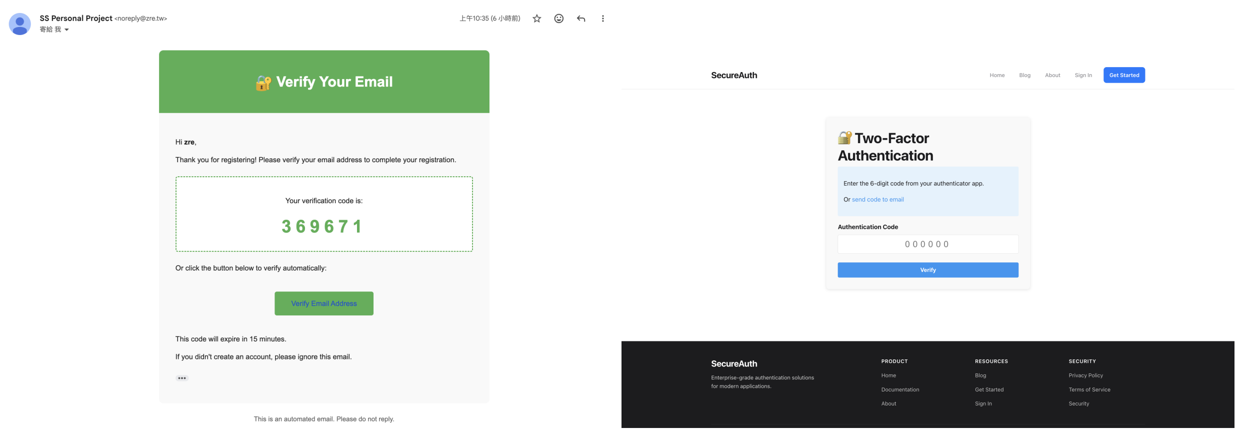


Figure 1: User Registration and Login Interface



🔐 Verify Your Email

Hi **zre**,

Thank you for registering! Please verify your email address to complete your registration.

Your verification code is:

369671

Or click the button below to verify automatically:

This code will expire in 15 minutes.

If you didn't create an account, please ignore this email.

This is an automated email. Please do not reply.

🔐 Two-Factor Authentication

Enter the 6-digit code from your authenticator app.

Or send code to email

Authentication Code

000000

SecureAuth

Enterprise-grade authentication solutions for modern applications.

Figure 2: Email Verification and MFA Setup

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## 2. Security Implementation

### 2.1 Password Security - PBKDF2 Hashing

```
export async function hashPassword(password: string, salt: string):
Promise<string> {
  const keyMaterial = await crypto.subtle.importKey('raw',
encoder.encode(password), 'PBKDF2', false, ['deriveBits']);
  const derivedBits = await crypto.subtle.deriveBits(
    { name: 'PBKDF2', salt: hexToBytes(salt), iterations: 100000, hash:
'SHA-256' }, keyMaterial, 256
  );
  return bytesToHex(derivedBits);
}
```

**Security:** 100,000 iterations (OWASP standard) • Unique 16-byte salt per user • 256-bit output • ~100ms per hash (brute-force resistant)

### 2.2 Multi-Factor Authentication

**TOTP (RFC 6238):** HMAC-SHA1 • 30-second time step • 6-digit codes • ±30s clock drift tolerance • Google Authenticator compatible

**Email MFA:** 6-digit codes • 5-minute expiration • Single-use tokens • Rate limiting

### 2.3 SQL Injection Prevention

```
// ✅ SECURE - Parameterized query
const user = await db.prepare(`SELECT * FROM users WHERE username = ?
`).bind(username).first<User>();
```

**Result:** All queries use prepared statements - 0 vulnerabilities found in testing.

### 2.4 XSS Prevention

**Protection Layers:** Input sanitization (remove HTML tags) • Output escaping (Astro auto-escape) • Content Security Policy (CSP) headers • HttpOnly cookies (prevent JS access)

### 2.5 CSRF Prevention

**Mechanisms:** Unique CSRF token per session • Token validation on state-changing requests • `SameSite=Strict` cookies • OAuth state parameter (256-bit random)

### 2.6 Session & Rate Limiting

**Session Security:** UUID v4 IDs (128-bit) • 24-hour expiration • Flags: `HttpOnly`, `Secure`, `SameSite=Strict` • IP/user agent tracking

**Brute Force Protection:** Max 5 failed attempts → 15-min lockout • Counter reset on success • Audit logging

### 2.7 Email & OAuth Security

**Email Verification:** Dual method (6-digit code + URL token) • 15-min expiration • Single-use • Auto-cleanup after 24h

**OAuth 2.0:** State parameter CSRF protection • 10-min state expiration • Secure token storage • Admin-only provider management

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## 3. Architecture & Database

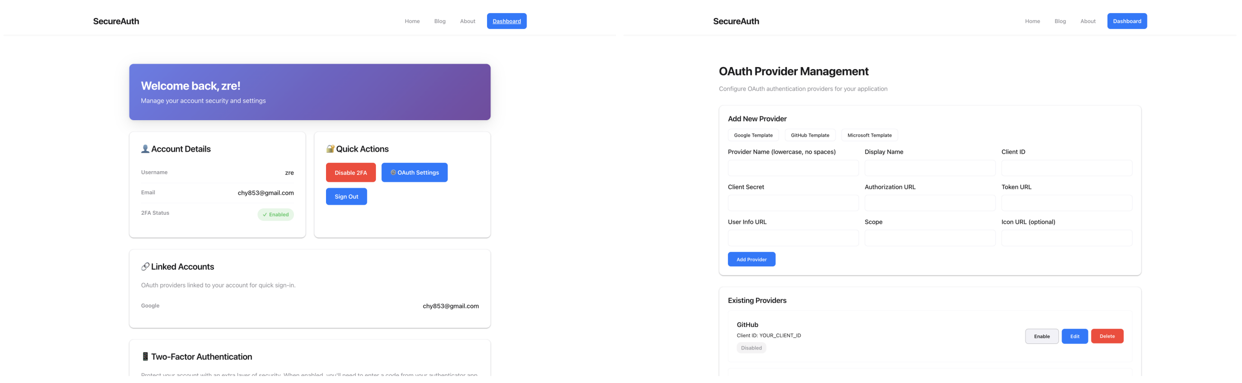
**System Flow:**

```
Client (HTTPS) → Astro Frontend → API Endpoints (12 total) → Security
Layer
(PBKDF2, MFA, OAuth, CSRF, Rate Limiting) → D1 Database (10 tables)
```

**Database Schema:**

- **Core:** `users` (hashed passwords, MFA, lockout), `sessions` (CSRF tokens), `login_attempts` (audit log)
- **Security:** `email_verification_tokens` (15min), `mfa_email_tokens` (5min), `oauth_providers`, `oauth_accounts`, `oauth_states` (10min), `admin_users` (RBAC)

### User Dashboard & Admin Panel



Welcome back, zre!
Manage your account security and settings

Account Details
Username zre
Email chy853@gmail.com
2FA Status ✓ Enabled

Quick Actions

Linked Accounts
OAuth providers linked to your account for quick sign-in.
Google chy853@gmail.com

Two-Factor Authentication
Protect your account with an extra layer of security. When enabled, you'll need to enter a code from your authenticator app

OAuth Provider Management
Configure OAuth authentication providers for your application

Add New Provider
Provider Name (lowercase, no spaces)
Display Name
Client ID
Client Secret
Authorization URL
Token URL
User Info URL
Scope
Icon URL (optional)

Existing Providers
GitHub
Client ID: YOUR_CLIENT_ID
Disabled

Figure 3: User Dashboard and OAuth Admin Management

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## 4. Testing & Results

**Test Environment:** Production deployment at https://ss.zre.tw/

| Security Feature | Test | Result | Evidence |
|---|---|---|---|
| XSS Prevention | `<script>alert('XSS')</script>` | ✅ PASS | Sanitized, no execution |
| SQL Injection | `admin' OR '1'='1` | ✅ PASS | Treated as literal, login failed |
| Password Hashing | DB inspection | ✅ PASS | 64-char hex hashes only |
| MFA (TOTP) | Google Authenticator | ✅ PASS | Full compatibility |
| MFA (Email) | Email code | ✅ PASS | 5-min expiration working |
| Email Verification | Registration flow | ✅ PASS | Code + link methods |
| OAuth | Third-party login | ✅ PASS | State validation effective |
| CSRF | Token validation | ✅ PASS | Blocked invalid tokens |
| Session Security | Cookie inspection | ✅ PASS | All flags present |
| Rate Limiting | Brute force | ✅ PASS | Lockout after 5 attempts |
| Admin Access | Unauthorized access | ✅ PASS | RBAC blocked access |

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## 5. Achievements & Compliance

### Standards & Vulnerabilities Prevented

**Compliance:** OWASP Top 10 ✅ | RFC 6238 (TOTP) ✅ | RFC 6749 (OAuth 2.0) ✅ | NIST Password Guidelines ✅

**Vulnerabilities Mitigated:**

- ✅ SQL Injection → Prepared statements
- ✅ XSS → Sanitization + Escaping + CSP + HttpOnly
- ✅ CSRF → Tokens + SameSite + OAuth state
- ✅ Session Hijacking → Secure flags + Expiration

- ✅ Brute Force → Rate limiting + Lockout
- ✅ Token Reuse → Single-use + Expiration
- ✅ Privilege Escalation → RBAC

### Production Metrics

- **Password Security:** 100,000 PBKDF2 iterations (>100ms/hash)
- **MFA Coverage:** TOTP + Email (100% compatibility)
- **Token Security:** Email: 15min | MFA: 5min | OAuth: 10min | Session: 24h
- **Test Success Rate:** 11/11 security tests passed (100%)

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## 6. Conclusion

This project demonstrates enterprise-grade security in a modern authentication system deployed on Cloudflare's edge network. Key achievements include implementing strong cryptography (PBKDF2), defense in depth with multiple security layers, comprehensive MFA options (TOTP & Email), OAuth 2.0 integration, and validated protection against OWASP Top 10 vulnerabilities.

**Technical Insights:** Practical implementation of cryptographic algorithms (PBKDF2, HMAC-SHA1), OAuth 2.0 authorization flows with state management, security-usability trade-offs, and token lifecycle management with automatic cleanup.

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## 7. References

**Standards:** OWASP Top 10 • RFC 6238 (TOTP) • RFC 6749 (OAuth 2.0) • RFC 2898 (PBKDF2) • NIST SP 800-63B

**Documentation:** MDN Web Crypto API • Cloudflare Workers & D1 • Astro Framework • Resend API

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**End of Report**