Recent BRANZFIRE enhancements and validation

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Summary
BRANZFIRE is a multi-compartment fire zone model that has been under development since 1996 predominately by Colleen Wade at BRANZ. The model includes flame spread routines, sprinkler/detector activation, mechanical extract/supply, tenability assessment, glass fracture and oxygen-constrained burning. The software is commonly used by fire engineering in New Zealand.

The full article briefly describes the result of projects carried out by students and staff at the University of Canterbury in conjunction with Colleen Wade. Projects have included the following:

- The addition of a glass breaking module which predicts glass ‘fracture’ of single glazed, rectangular (and planar) windows;
- An investigation of sprinkler performance when using different ceiling jet correlations and the prediction of the activation time of recessed and concealed sprinklers;
- An assessment of model predictions with fire experiments carried out in a two-storey house. Comparisons were made for layer conditions including temperature, height, optical density and also the performance of smoke alarms.
- Initial work to try to validate the algorithms used to model smoke flow through horizontal vents and
- Improvements in the transfer of construction data from building information modelling (BIM) applications into BRANZFIRE.

Introduction
This article is based on a presentation given at the SFPE New Zealand Chapter Annual General Meeting in November 2007 and describes the result of projects carried out by students and staff at the University of Canterbury in conjunction with Colleen Wade at BRANZ. The article can only provide a short summary of each piece of work and a list of references is given so that the reader can investigate a topic in further detail.

The BRANZFIRE simulation software has been under development since 1996 predominately by Colleen Wade (2004). It is a multi-compartment fire zone model including flame spread routines. It also models sprinkler/detector activation, mechanical extract/supply tenability assessment, glass fracture, oxygen-constrained burning. The software is commonly used by fire engineering in New Zealand and is also occasionally used by the international community.

Glass breaking module
A glass breaking module has been added to BRANZFIRE based on work then available in the literature. The module provides prediction of glass ‘fracture’ not fall-out as the percentage fall-out is uncertain and difficult to predict. The module is suitable for single glazed, rectangular (and planar) windows.

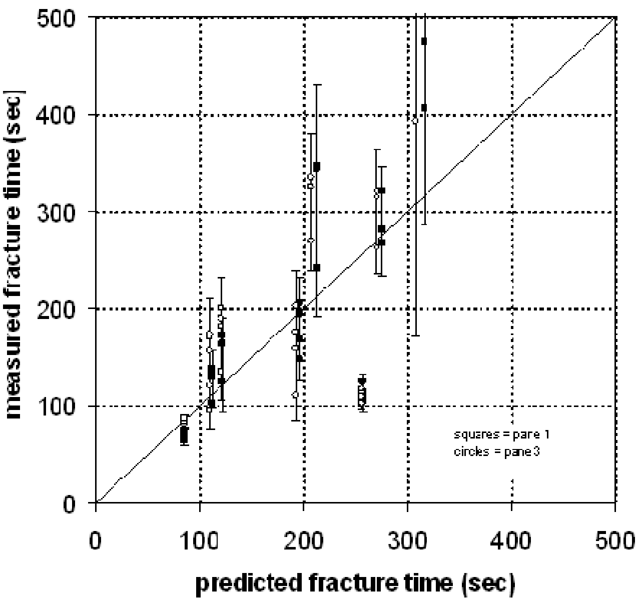


Figure 1. Comparison of predicted versus measured glass fracture times (error bars span two standard deviations) – from Parry *et al.* (2003).

The approach assumes full immersion and uniform heating of glass, no thermal shocks such as sprinkler spray and no out-of-plane loading (e.g. wind). A glass fallout time can be manually set. Validation of the module showed a reasonable match with previous methods and data (Figure 1).

Sprinkler performance

Several items of research have investigated the predictive capability for sprinkler activation time. BRANZFIRE includes the option to use either Alpert's unconfined ceiling jet correlation or NIST's JET model to obtain the fire exposure conditions for the sprinkler head.

Data from fire experiments conducted by Bittern was used for the comparison of the activation time of sprinkler heads exposed to the fire gases on the ceiling. Each experiment included a pair of standard or residential sprinkler heads located in an apartment size room. The fires consisted of upholstered seats located both at the room centre and a corner. An external door to the room was left open or closed during an experiment.

It was found that much a better agreement between the simulations and the experiments was achieved with JET model over Alpert's correlations. Times to sprinkler activation were approximately 20% slower than experiment in base case scenario using JET model (Figure 2). The position of sprinkler head beneath ceiling was found to be an important parameter as it has strong influence on the ceiling jet temperature applied to the sprinkler head. The likely variability in RTI and C-factor found to be not so critical.

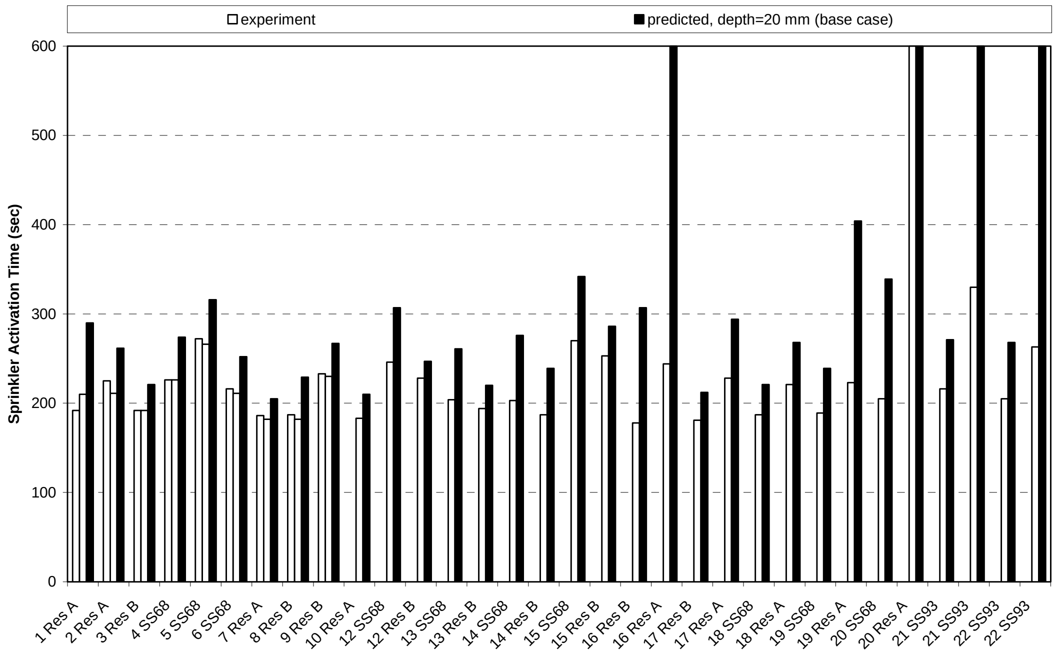
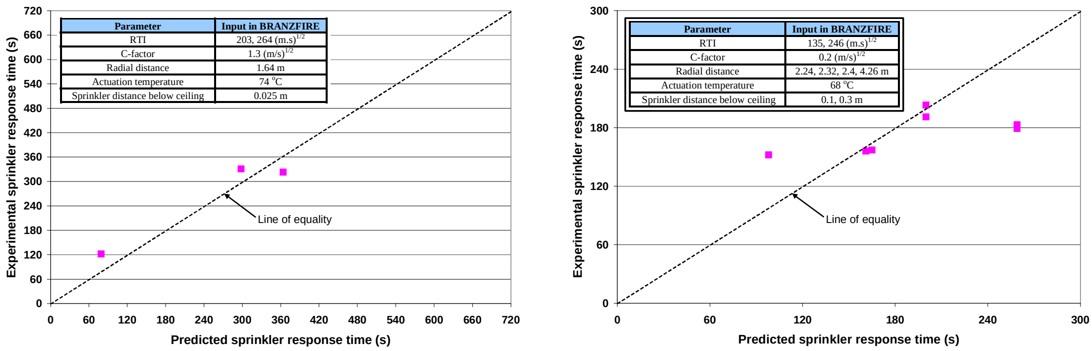


Figure 2. Comparison of measured and predicted exposed sprinkler activation times for base case with BRANZFIRE/JET model – from Wade et al. (2007).

Further work has been carried out to examine how the activation time of recessed and concealed sprinklers might be predicted in BRANZFIRE. In this case the sprinklers were characterised using apparent Response Time Index (RTI) and conduction factor values obtained in wind tunnel experiments completed at the University.



(a) (b)

Figure 3. Comparison of measured and BRANZFIRE predicted sprinkler activation times using 'best' input parameters (a) concealed sprinklers; (b) recessed sidewall sprinklers – from Yu (2007).

BRANZFIRE predictions were then compared with a series of room fire experiments detailed in the literature which included exposed, concealed and recessed sidewall sprinklers. A sensitivity analysis of BRANZFIRE parameters was undertaken and a reasonable match was obtained when appropriate 'best' input values were selected (Figure 3).

Comparison with house fire experiments

This work was a validation exercise through a comparison with full-scale house fire experiments conducted at BRE. The experiments were carried out in a two-storey house in which arm-chair fires were set in its lounge. The windows closed and oil-filled radiators used to simulate heating that might be used during winter. During the experiments layer heights, temperatures, gas concentrations, optical densities and smoke alarm activations were measured in the lounge, hallway, stairs and bedroom. These measurements were compared with predictions made by BRANZFIRE such as shown in Figure 4 for a combustion-modified high resilience foam and flame retardant cotton backed Dralon armchair.

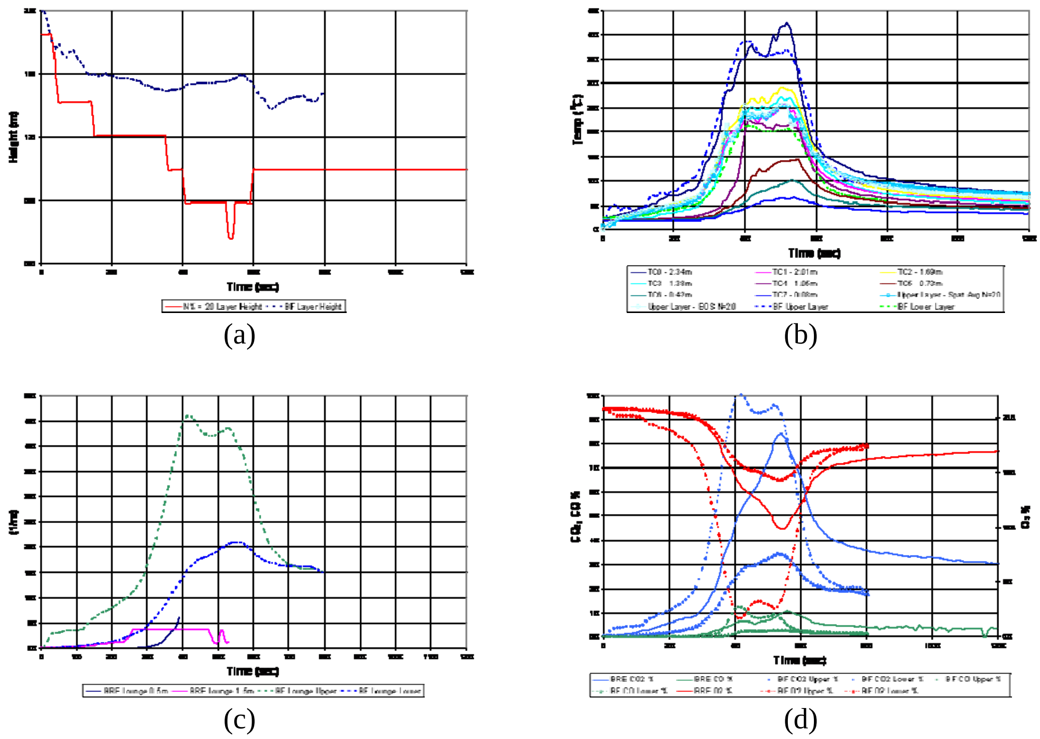


Figure 4. BRANZFIRE predictions and measured data for the lounge in Cardington House experiment CDT 18; (a) layer height; (b) layer temperatures; (c) optical density; (d) gas concentrations – from Thomas (2007).

The success of interface layer height and temperature BRANZFIRE predictions depended on the room considered. The layer interface height was comparable to the experiments in the majority of the compartments but BRANZFIRE tended to under-predict the descent of the layer in the bedroom. Upper layer temperatures in the lounge were higher than those recorded in the full scale testing. Temperatures predicted in other compartments were the same as or less than those recorded in the full scale experiments.

It was found that the optical density predictions too high and it is clear that more research needed to investigate smoke yields from fuels and implementation of the yield generation in BRANZFIRE. The activation of smoke alarms was predicted by BRANZFIRE earlier than in the experiments regardless of whether photo-electric or ionisation devices were considered (Figure 5). The reason for this appeared to be partly due to the high optical densities calculated by BRANZFIRE. However, BRANZFIRE correctly determined the activation order of the smoke alarms in which those further from the fire responded later than those close to the fire as would be expected.

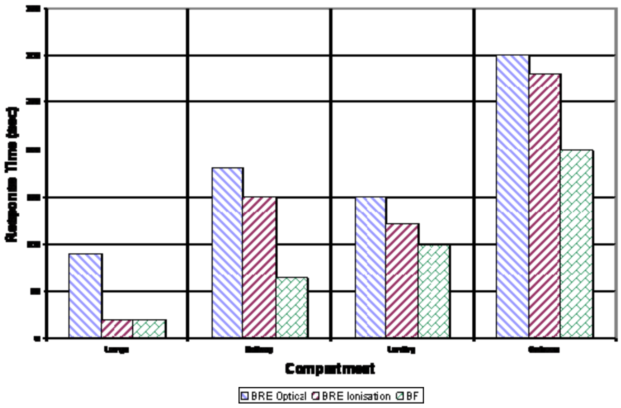


Figure 5. BRANZFIRE smoke alarm activation predictions and measured data in Cardington House experiment CDT 18 – from Thomas (2007).

In terms of gas concentrations it was found that the reduction in O_2 was over-predicted, CO under-predicted and CO_2 over-predicted but general trends were qualitatively similar to the experiments. The BRANZFIRE simulations generally gave a good estimate of the fractional effective dose due to heat and due to asphyxiant gases not including hydrogen cyanide in the lounge. However a very poor prediction of the fractional effective dose due to both gases and heat was determined for the bedroom.

The research also examined the hall / stair / landing geometry in which one arrangement used two compartments to describe the three rooms, the other used three compartments (Figure 6). It was found that there was little difference in a number of the variables predicted by BRANZFIRE. Consequently it was difficult to recommend any one arrangement as some outputs provided a better prediction in one case over another.

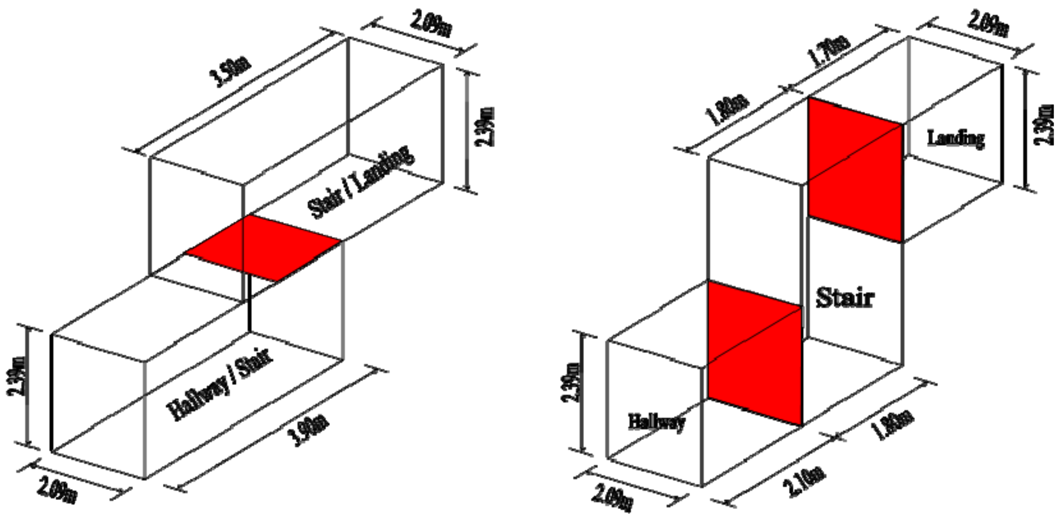


Figure 6. The hall / stair / landing geometry configurations investigated in the BRANZFIRE simulations of the Cardington House experiments – from Thomas (2007).

Horizontal vents

The original intention of this work was to validate the horizontal (ceiling) vent flow algorithm implemented in BRANZFIRE. The algorithm had been developed by Cooper using data from the literature however it was found that very little of the data was useful for this research. Instead a comparison with Fire Dynamics Simulator (FDS, version 3.1) predictions was conducted as an alternative. Clearly this was not a validation in its correct sense but did provide a basis for an assessment of the performance of BRANZFIRE.

The comparison varied a number of parameters including the fire size, fire location, vent dimensions and the FDS grid size. In most cases a single horizontal vent was positioned in the centre of an ISO room equivalent compartment.

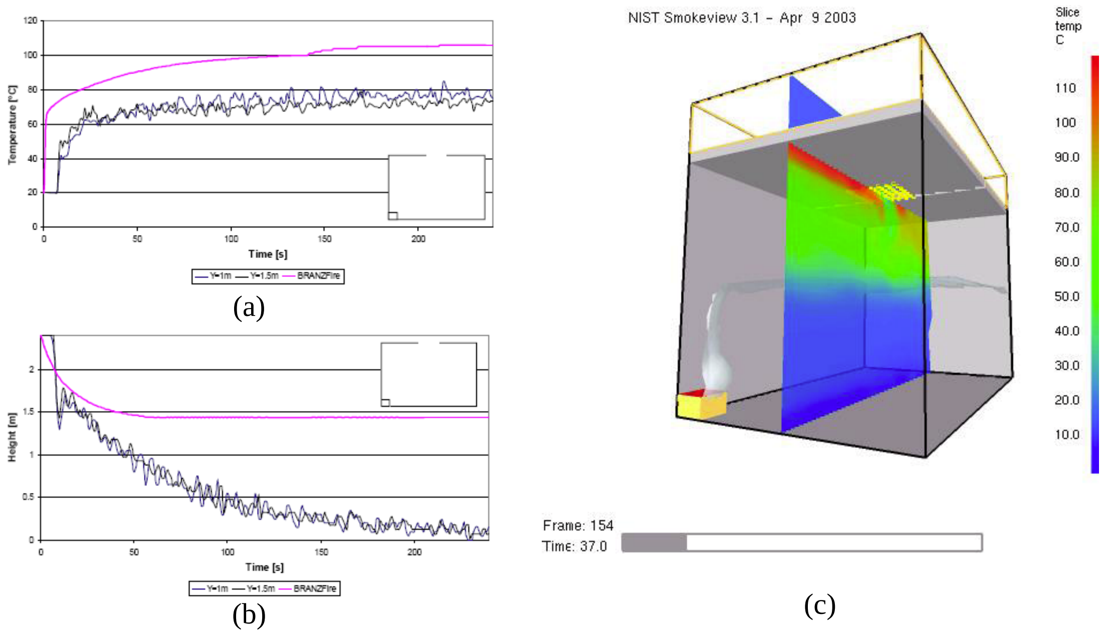


Figure 7. Comparison of BRANZFIRE and FDS results for a 50 kW corner fire with a 1.20 m horizontal vent; (a) upper layer temperature; (b) layer height; (c) typical FDS SmokeView results – from Mills (2004).

Results such as those shown in Figure 7 found that BRANZFIRE predictions of layer height and temperature are reasonable during the early stages of a fire. However the predictions steadily worsen due to a lack of entrainment / mixing modelling for the inward flowing air stream. The upper layer temperatures were over-predicted and interface was found to fall far more slowly than was indicated by FDS. Salt water experiments are currently underway at the University to obtain a good set of data for future validation of both BRANZFIRE and the latest version of FDS.

Data exchange

BRANZFIRE has been linked to an external online database of rate of heat release information. The database system includes facilities to search database and extract items into the model. The database is extended when resources allow meaning that BRANZFIRE users always have access to the latest records within the database.

Another ongoing project is investigating the exchange of electronic building information with BRANZFIRE (and other models). Translation is achieved from commercial software through the Industry Foundation Classes (IFC) object-oriented data structures. The IFC data structures can be exported from building information modelling (BIM) applications such as Graphisoft's ArchiCAD 9 and AutoDesk's Revit 9.0.

Identification of mapping paths between the IFC and BRANZFIRE input files to determine compartment dimensions, boundaries and vent connections (Figure 8). Currently the exchange process is suitable for 'simple' single-storey buildings. There are many challenges yet to overcome including: complex shaped rooms, multi-storey buildings, material properties, active fire systems and usability of the exchange software.

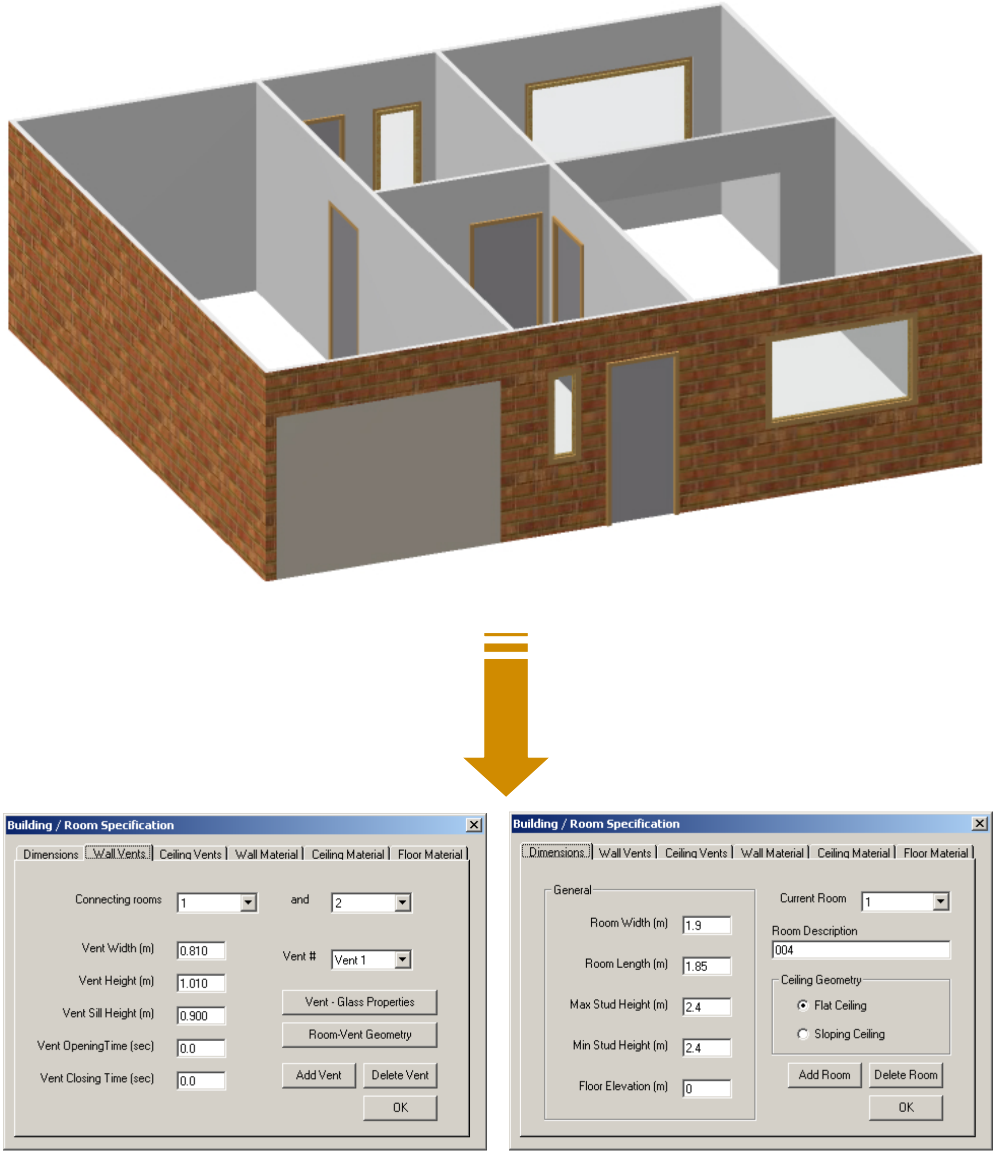


Figure 8. Exchange of ground floor of Cardington House geometry created in ArchiCAD with BRANZFIRE.

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