ITU A|Z
VOL: 5 NO: 1, 1-11 2008-1

Examination of safe boundary distances; Dwelling cases from Istanbul

Nuri SERTESER
Istanbul Technical University Faculty of Architecture Istanbul TURKEY

Received: July 2007 *Final Acceptance: March 2008*

Abstract:
Although many ways of spreading fire between existing buildings, radiation is one of the effective ways of it. In this study, safe boundary distances for preventing ignition by fire radiation between the buildings facing each other are examined as regards appropriateness of the distances by using some calculation methods still valid on this area. For the application of these methods two old and one modern building are chosen as cases. The importance of the boundary distance arises especially in the old and historical city parts because of the narrow streets, close distances between buildings and the use ignitable materials on facade and construction of such buildings. The modern building sample is chosen from Atasehir reflecting the contemporary and civil face of the city. Some calculations to obtain safe boundary distances are made on the case buildings chosen and the results of the applications in tabulated form are compared with each other. As a result the existent separation distances are not sufficient for fire protection against radiation for the old buildings whereas the modern building satisfies. Especially for the protection of the historical properties made of ignitable materials and placed each other very closely some fire protection measurements must been taken against fire radiation and the other ways of fire spread.

Keywords: *Building fires, fire radiation, safe boundary distance*

Introduction

Spreading fire between buildings takes place by flying brands falling on or inside of buildings by conveying of hot flaming gases by convection and by radiation (Aydın, 1998), (Yavuz, 1996).

The first and may be the most important factor in propagation of fire between buildings is radiation. The effects can reach much bigger distances comparing to the direct flame and convection (McGuire, 1965a). The results can be recognized too later by reason of being invisible. So the harmful mechanism works without distinguishing.

The radiation intensity would be different depending on the fire risk of the building (Becan, 1994). The amount of openings on the outer wall, fire resistance of glass and the sash used in openings, material characteristics of coverings has also major effects in fire propagation by radiation between buildings. The effect changes by the distance between buildings or to the boundary. As the distance ascends the buildings are stay in safe relatively.

The widely used calculation methods for determining the safe boundary distances

Some widely used methods are used for control purposes and also used for as design tools for a fire safe building for calculation are as follows:

Enclosing rectangles method (geometric method)

It is used for determining the boundary distance of a building by comprising the whole unprotected areas of the façade in rectangles. According to the rectangles' dimensions and proportion of the unprotected area a table gives the minimum boundary distance. The table constituted for different use of buildings can be used by designers who never familiar to the fire engineering subjects sufficiently (Fire Research Station, 1991).

Aggregate notional areas method (protractor method)

Several points are taken on the relevant boundary and the amounts of unprotected areas on the façade that can be viewed from those points are calculated. Those areas are mentioned as effective or notional areas and are multiply by a coefficient depending on the distance. The amount of total notional areas must be less or equal to the values determined before. This method also known as "protractor method" is preferred for more complex buildings by using with "enclosing rectangles" (Fire Research Station, 1991).

Peter Collier's method

This method by Collier makes user possible to define the fire intensity frankly depending on the real building and the features of it. The aim of this method is to impede fire amongst the neighbor buildings. The method makes user to define or calculate the temperature of a compartment possible. The critical amount of radiation for ignition can be changed depending on the covering of the neighboring building (Carlsson, 1999).

C.R. Barnett's method

This method by Barnett can be used in newly designed buildings and also in critical conditions for existing buildings. The method is considered depending on the resistant-to-fire degree of a building. The calculations can be done in two ways; either the unprotected permissible amount of openings can be calculated or the amount of total radiation received by the neighbor building can be determined (Barnett, 1988).

J.H. McGuire's method

The safe building distances can be determined according to the tables that arranged to the dimensions of the compartment, proportion of the unprotected area of the façade and the hazard risk group of the building. The unprotected areas for fire on a façade can be accepted as openings (McGuire, 1965b).

NFPA 80A's method
It aims at protect to the combustible materials as inside as outside of the building from effect of an external fire source. The document is prepared to constitute a guide for insurance for protection of the buildings being exposed to an external fire (NFPA 80A, 1991).

Discussion of the calculation methods
All calculation methods mentioned above have been developed by different applicants in different dates and have differences in some ways. While some constants like configuration factors extracted from the results of the experimental works are used in some of the methods, the others collect and use the data from existing conditions. In some methods the boundary distances are taken from a plane of reference by reflecting the unprotected areas on it. While in some methods the horizontal extension of the flames running over outside of the building from unprotected openings is considered in calculation whereas it is neglected in some others. As a common point of these methods is the unprotected areas on the façade are taken into rectangles for determining the hazardous amount for fire like in the enclosing rectangle method. Sometimes the unprotected areas may constitute just a little percentage of these rectangles because of the data taken from the table of original method. The similar and different ways of these methods are expressed in tabular form below (Table 1). The aggregate notional areas method that's because used with enclosing rectangles method is not placed on the table separately.

Table 1. *The similar and the different ways of calculating methods (Serteser, 2004)*

	1	2	3	4	5	6	7	8
Barnett	•		•			•	•	•
McGuire	•	•		•	•			
Collier	•		•	•		•	•	
Enclosing rectangles		•	•	•	•			
NFPA 80A	•	•	•		•			

1: Taking flame propagation into account; the dimension of horizontal extension of the flames running over the unprotected openings of the buildings is taken into account in all methods except the enclosing rectangles method. The results should be evaluated keeping this difference amongst the methods on mind.

2: Allowing performance-based design; radiation and configuration factors are taken as constants in methods of McGuire, enclosing rectangles and NFPA 80A. These values have been used in calculations as constants extracted from the experimental results. Making calculations by using these constants are reduced the flexibility of the applications. Besides because of the higher configuration factors of McGuire's method the safe boundary values are higher in comparison with the other methods and this makes the comparison difficult. Whereas using the existing data as input to the calculations make the results more reliable and make the performance-based design possible in Collier's and Barnett's methods.

3: Applicability to the complex building forms; all the calculation methods except McGuire’s can be applicable to the more complex building forms easily. If any difficulties arise in application of enclosing rectangles method for the complex building forms the protractor method can be used for making application more reliable. Just being applicable for the buildings having openings orderly on the façade lessens the applicability and the reliability of McGuire’s method.

4: Referring to the plane of reference; the calculation methods except Barnett’s and NFPA 80A’s require to take the whole unprotected openings into account by projecting them on a plane of reference. The measurements are taken to the plane of reference in determining the safe boundary distances. The plane of references are determined to the application of the methods if any set backs or projections exist on the building façade. So the boundary distances change in the presence of the set backs and/or projections on the façade.

5: Easiness of application of the methods; some methods except Barnett’s and Collier’s that make the performance-based design possible utilize some tables to facilitate the application. So it’s not necessary for the users of these methods to be a fire expert. Whereas using the data of the building for the calculation in Barnett’s and Collier’s methods requires the people familiar to the subject of fire.

6: Taking the fire temperature into consideration; fire temperature is just inserted in the calculations of Barnett’s and Collier’s methods. The fire temperature of the compartment in fire is obtained by calculation. But in Collier’s method differ from Barnett’s fire temperatures and ambient air temperatures are neglected.

7: Taking the radiation intensity into consideration; the radiation intensities are just taken into consideration in Barnett’s and Collier’s methods. These values are determined to the fire temperature values of the building in fire. Consequently without taking the building outside air temperature into account in calculation of fire temperature, the radiation intensity is also neglected in radiation calculations in Collier’s method.

8: Taking the building outside air temperature into consideration; as implied above matters in calculating of fire temperature and radiation the building outside ambient air temperature is just used in Barnett’s method (Serteser, 2004)

Calculation steps

The calculations for the safe boundary distances have been done by using the steps of Collier’s method. This method has more advantages than the others e.g. it is the latest study on this subject, can be used while designing, poses calculation possibilities according to the real data and changing parameters of the building and gives an opportunity to determine radiation intensity more preciously. The calculation steps are as follows:

Step 1: Determining amount of rectangular areas.
The unprotected areas of the façade transform to the more little rectangular areas for calculation. A reference plane touching to the projecting parts of the façade that’s not flat is drawn for calculating the real areas by reflecting the unprotected areas on it.

Step 2; Calculation the area of enclosing rectangle (A_e)
$A_e = H \times W$ [m^2] (1)
H = Height of rectangle [m]
W = Width of rectangle [m]

Step 3; Finding aspect ratio (AR)
AR = H/W (or W/H) AR≤1 (2)

Step 4: Determination radiation intensity in the fire compartment (I_S)
$I_s = 5.67x10^{-11} xT^4$ [kW/m^2] (3)
T = Fire temperature [°K]
Various appropriate or calculated values of fire temperatures can be chosen but in general a temperature of 1000 °C can be taken for the calculations.
$T = 345\log_{10}(8t+1)$ [°C] (4)
t = Fire resistance time of the compartment [min]

5: The whole façade can be accepted as radiating surface if the external wall of the building on fire is not fire resistant. However if the wall is fire resistive the radiation intensity can be reduced to a certain amount by a reduction factor (R_f). This can be calculated with Equation 5.
$Rf = A_o/A_e$ (5)
A_o = Unprotected areas [m^2]
A_e = Area of the rectangle [m^2]

Step 6: Calculating the radiant flux (I_e) emitted from the building on fire. This value can be reduced by an additional 50% if the building on fire is fitted with fire resistive glasses in unprotected openings. Amount of emitted flux (I_e), can be calculated with Equation 6.
$I_e = I_S \times Rf$ [kW/m^2] (6)

Step 7: Determination of critical radiation value (I_{cr}) that can ignite the neighboring building. This depends on the cladding type and the glass characteristics being used on the openings of the building. The radiation gain through openings can be reduced by 50% if fire resistive glazing is being used on the unprotected openings of the façade. If not the glazing can be broken easily in higher radiation intensity is assumed.

Step 8: Calculation of acceptable configuration factor (ϕ).
$\phi = I_{cr}/I_e$ (7)

Step 9: Calculation of separation distance (S) between buildings.
$S = R + P$ [m] (8)
R = Radiation distance taken from Figure 1 [m]
P = Projection distance [m]

The projection distance is taken 2 m. if non fire-rated glazing is used on the openings of the building otherwise it is taken 0 m. Different values can also be used if it's obtained by the sufficient calculations.

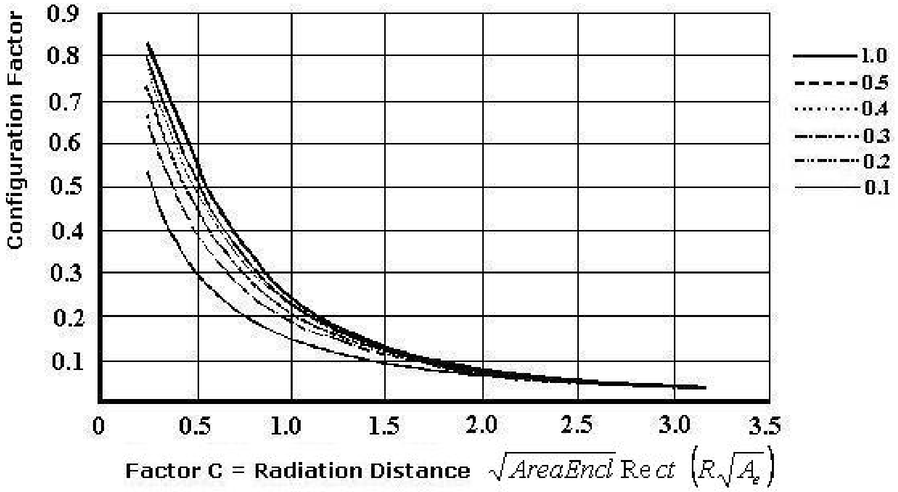

Figure 1. *Configuration factor and radiation distance relations*

Application of the method to the sample buildings selected in Istanbul

Application has just been realized in residential buildings because of the high fire frequency according to the fire brigade statistics of Istanbul. The city has also a great historical past. Most of valuable historical properties are still living as mixed with the newly constructed buildings. While some of these old buildings are used by their owners or tenants whereas some of them have turned debris by reason of lacking good care. The flammable materials like wood have been used in construction and/or on façade in general and any special precaution has not been taken against ignition. Lots of the buildings especially wooden ones destroy by disasters like fire every year. If a fire occurs in an old building it can be affect most of the neighboring buildings in a short time. Narrow streets and adjacent settlements of old city parts enhance the risk of fire at the same time. The reason of narrowness of these streets and the parked cars fire engines couldn't reach to the buildings in fire and the fire brigade's intervention is restrained. So the two sample buildings are selected from old city to examine the boundary distances.

The other case building has been selected from Atasehir the modern face of the city. The buildings of Atasehir have been constructed with reinforced concrete and in skeletal construction. The streets dividing the block of houses have been planned extremely wide and the houses have been settled detached or attached with another in general. This modern case building has been taken especially to compare the results of two other old buildings as regards of the boundary distance.

Application study 1: Examination of two old buildings with wood and brick constructed façades

The buildings examined are placed upon Parmaklik Street of Zeyrek area that is one of the historical zones of Istanbul. The buildings consisting of the street silhouette are wooden construction with 2 or 3 storey harmonized with the old view in general. But also some new buildings that are not suitable as material characteristics as the architectural view of the street have been constructed in place of the demolished ones especially along with the one side of the street by the time. Settlement of the selected buildings on the street can be seen in Figure 2.

The two buildings have been selected to have façade features of projecting both old and new view of the street, one of wood veneer and the other of cement plastered and are also settled facing one another on the street.

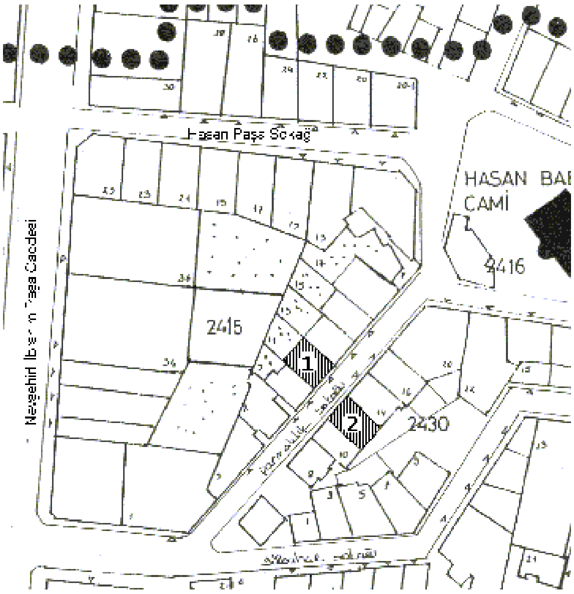

Figure 2. *Selected buildings on the street*

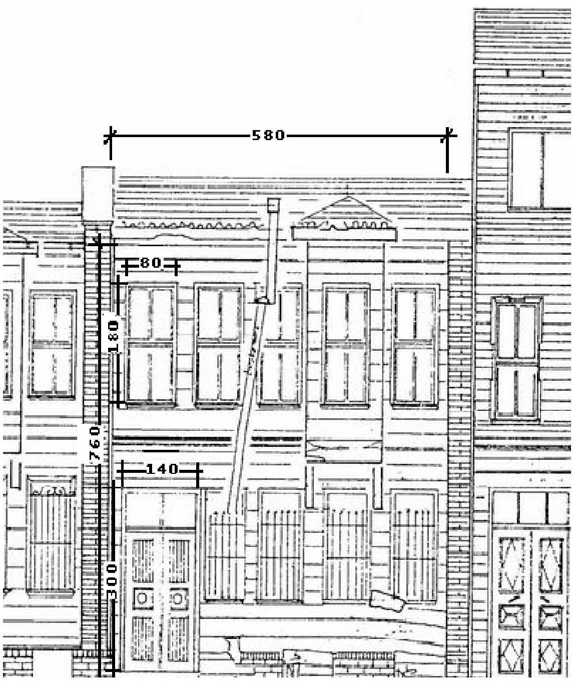

Figure 3. *Elevation of the first building*

The first building examined is consisting of two storeys with high basement level. The building has a brick masonry construction and has been separated with brick walls from the neighbors in both sides but the walls have not sufficient height for a fire passing through the roof. A projection part of 0.8 m. in second floor is not considered in calculation because of its dimension. The external wall of the building has been coated with plaster inside and wood veneer outside but has not provided with enough fire resistance. All window and door openings of the façade contain woodworking has burning features. The elevation of the first building can be seen in Figure 3.

The second building examined is constructed with reinforced concrete in skeletal construction and consisting of basement+3 storey. The external wall has been coated with cement plaster having nonflammable character. All building openings and façade are thought as irradiating because any fire compartment is not contained with the building, i.e. a fire is predicted to involve the whole building. The elevation of the second building can be seen in Figure 4.

It's estimated that the duration of the fire will be 30 minutes. The fire temperature is 842 °C from the formula derived from ISO 834 fire curve and the radiation intensity would be 87.15 kW/m^2. The critical incident radiation level is (I_{cr}), 12.5 kW/m^2.

The aim of this calculation is the building is separated from the boundary by at least half the distance and the total amount of radiant heat flux received from all unprotected parts in the external wall would not exceed 12.5 kW/m^2. The distance to the relevant boundary that is an actual or an assumed boundary placed in the middle in the space between two buildings has been determined. An identical building has also been placed on the other side and the same distance to the relevant boundary. Calculations for safe separation distances have been done for the both case buildings by the steps mentioned above.

Application study 2: Examination of brick constructed modern residential building

The case from Atasehir differs from the previous cases by urban settlement and architectural style. General settlement of the case building can be seen in Figure 5.

The building examined is consisting of basement+7 storeys constructed with reinforced concrete in skeletal form and contain 2 apartments in each storey. It's accepted that external walls and floors has sufficient fire resistance but special precautions against fire are not taken for the openings on the façade. The elevation of the building can be seen in Figure 6.

The floor slabs of the building are also accepted resistant to fire for 90 min. and all storeys are considered as fire compartment. The block looks at a wide parking area in one side. It's thought that fire occurred in an intermediate story facing to the parking area as shown in Figure 6. For the calculation purpose two of the same buildings are accepted as if settled in the same distance to the border line.

It's thought that fire will be effective in 30 min. and according to this condition the fire temperature obtained from the formula derived from the ISO 834 time-temperature curve is estimated 842 °C. Depending on this temperature the radiation amount calculated is 87 kW/m^2. Critical radiation value (I_{cr}) is taken 12.5 kW/m^2. The whole calculation results are summarized in Table 2 below (Serteser, 2004).

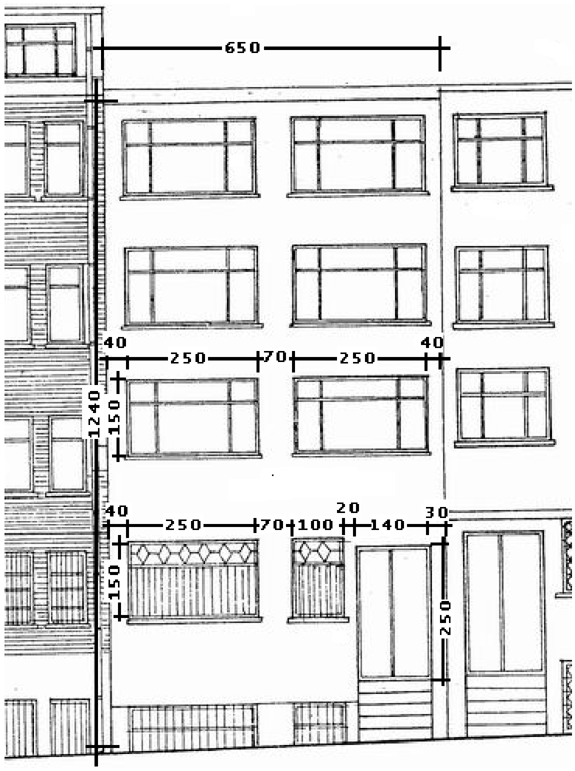

Figure 4. *Elevation of the second building*

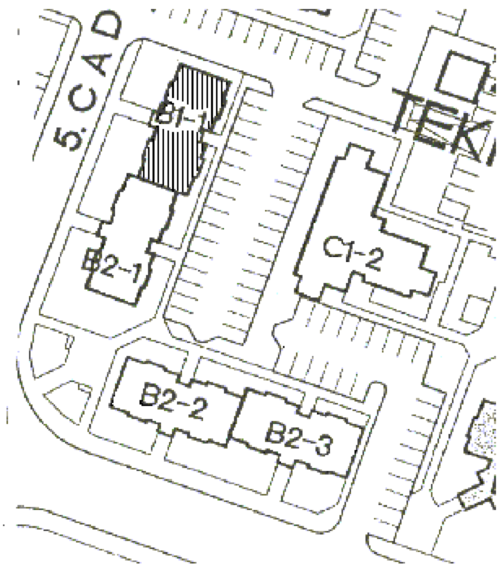

Figure 5. *General settlement of Ataşehir*

Figure 6. *The elevation of the building*

Table 2. ***Table 2.** The safe separation distances for the buildings examined (Serteser, 2004)*

	Old building with wood veneer façade	Old building with plastered façade	Modern building with plastered façade
Boundary dist. (m)	3.21	4.10	2.51
Separation dist. (m)	6.41	8.20	5.02

Conclusions and recommendations

As comparison with Collier's the safe boundary distances for these case buildings have been calculated and expressed in Table 3. After examination the values from the table quite different results can be recognized for the same application. These differences arise from the criteria accepted by the methods and the inputs used in calculations. Some results are comparably high depending on the constants that being used by some methods. . The distance between buildings would be more than it is required for fire protection if the methods use bigger constants. It should be necessary to evaluate the criteria that the method being used.

***Table 3.** Comparative results for the safe separation distances (Serteser, 2004)*

	Old building with wood veneer façade	Old building with plastered façade	Modern building with plastered façade
Barnett	3.48	6.20	2.34
McGuire	10.18	16.02	6.12
Collier	6.42	8.20	5.02
Enclosing rectangles	7.30	6.78	4.20
NFPA 80A	6.70	8.60	4.12

The importance of the separation distance arises especially in the old and historical city parts because of the narrow streets and close settlements of the buildings covered with easy ignitable materials. The calculated building separation distances are generally over the real distance between the buildings on different sides of the relevant boundary in the old city parts. The projections on the façade are characteristic part and are constructed in second storey and higher in general. Although this part's projection on the plan is passed over the border line to the street side, the distances between the buildings have been measured from the construction lines. However the measured separation distance between the two buildings is of 6 m. the calculated distance is of 6.41 m for the first old building and of 8.20 m for the second one in the case. The existent separation distances are not sufficient for fire protection against radiation. So if one of these buildings would be on fire, the fire could spread to the other building on the other side of the relevant boundary by radiation easily. One building fire could also be affect lots of the buildings in a short time by another ways of spreading mechanism except radiation. In addition the reaching difficulties of fire brigade to this kind of settlements enhance the hazard of destroying the buildings by fire.

The building separation distances are nearly the same with a little change along with the street in those settlements. The building materials used in construction, the iterative projections on the façade, the height of the buildings and opening rates on external walls and the roof shapes resemble each other in traditional architecture. The danger of fire is not taken consider in many buildings generally. Lots of them could destroy by a fire accidentally or deliberately.

On the other hand the calculation results for modern building show that the safe boundary distance is shorter than the old building cases. While the distance of 5.02 m is enough between buildings for protection from fire radiation the real distance is of 21.00 m to the nearest building. The existent distance is extremely enough for fire protection. In other words another similar building block can be settled closer to the case building comparing with other old building cases. The distances are more crucial for the old buildings in these conditions.

Some passive or active fire protection measures must be taken for this kind of building façades against to ignition by fire radiation. These measures are like application of fire resistant paints or intumescing coatings, covering with fire protective panels, using fire resistant windows and glasses, using sprinkler heads that will be protect the façade by moistening and using materials and furniture with low heat release inside of the building.

The applications have been done for the residential buildings that has “low” fire risk. The application of separating distance for the buildings in “higher” risk group also must be done for the control purpose.

The critical radiation value of 12.5 kW/m^2 accepted by the calculation methods although has been used in the applications; the new values for chancing façade materials should be taken (Serteser, 2004).

Symbols

A_e	*Area of the rectangle [m^2]*
A_o	*Unprotected areas [m^2]*
AR	*Aspect ratio*
H	*Height of rectangular area [m]*
I_{cr}	*Amount of critical radiation [kW/m^2]*
I_e	*Radiant flux [kW/m^2]*
I_s	*Radiation intensity in the fire compartment [kW/m^2]*
P	*Projection distance [m]*
ϕ	*Configuration factor*
R	*Radiation distance [m]*
R_f	*Reduction factor*
S	*Separation distance [m]*
t	*Fire resistance time of the compartment [min]*
T	*Fire temperature [°K]*
W	*Width of rectangular area [m]*

References

Aydın, C., (1998). **Yangının Çelik Taşıyıcı Sistemler Üzerine Etkisi ve Bir Uygulama Örneği**, *Y. Lisans Tezi,* İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul, 12.

Barnett, C.R., (1988). Fire Seperation Between External Walls of Buildings, **Fire Safety Science, Proceedings of the 2nd International Symposium**, 841-850.

Becan, A.S., (1994). K**onutlarda Bina Yangın Güvenliği Sorunlarını Gözeten Mimari Tasarım Kararları İçin Bir Yaklaşım Modeli Araştırması**, *Doktora Tezi,* İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul.

Carlsson, E., (1999). External Fire Spread to Adjoining Buildings, Lund University, **Department of Fire Safety Engineering, Report** *5051*, Lund.

Fire Research Station, (1991). **External Fire Spread:Building Separation and Boundary Distances**, Read, R.E.H. (editor), Construction Research Communications Ltd., London.

McGuire, J.H., (1965). Fire and Spatial Separation of Buildings, **Fire Technology**, Vol.1, No.4.

McGuire, J.H., (1965). Spatial Separation Tables, **Technical Note**, National Research Council of Canada, Division of Building Research.

National Fire Protection Association, (1991). **NFPA 80A Recommended Practice for Protection of Buildings from Exterior Fire Exposures**, Vol.9, NFPA, Quincy.

Sentürk, N. ve Özbek, İ., (2001). **Zeyrek Bölgesi Tespit ve Koruma Çalışmaları,** İ.T.Ü. Mimarlık Fakültesi Restorasyon Anabilim Dalı, Sit Koruma Projesi (Yürütenler: Prof.D. Kuban, Prof.Dr.Z. Ahunbay, Prof.Dr.N. Akın, Doç.Dr.A. Ersen, Yrd.Doç.Dr.G.Tanyeli, Y.Doç.Dr.Y. Kahya), Ö: 1/1000, 1/100, İstanbul.

Serteser, N. (2004). **Yanan Binadan Karşısındaki Binaya Işınımla Yangın Yayılımının Önlenmesi İçin Güvenli Sınır Mesafesinin Belirlenmesinde Bir Model Önerisi**, *Doktora Tezi*, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul, 69-77, 115-122, 127-129.

Tekfen İnş. ve Tes. A.Ş., 1989. **Ataşehir Uydukent Projesi**, 1. Etap, 48 Ada, Vaziyet Planı, İstanbul.

Yavuz, G., (1996). Yapılarda Yangın Korunumu-Mimari Tasarım Etkileşimi, **Y.E.M. Bina Yangın Güvenliği Seminer Bildirileri**, İstanbul.

Güvenli sınır mesafelerin incelenmesi; İstanbul'dan konut örnekleri

Binalar arasında yangının yayılmasında pek çok farklı yol olmasına rağmen, ışınım bu yollardan en etkili olanlarından birisidir. Bu çalışmada karşılıklı olarak yerleşmiş binalar arasında ışınım yoluyla tutuşmanın önlenmesi için güvenli sınır mesafeleri, uygunlukları açısından bu alanda halen geçerli olan bazı hesaplama metotları kullanılarak incelenmiştir. Bahsedilen metotların uygulanması için örnek olarak iki eski ve bir modern bina seçilmiştir. Sınır mesafenin önemi, dar sokaklar, binalar arasındaki yakın mesafeler ve cephe kaplaması ve konstrüksiyon malzemesi olarak yanıcı malzemelerin kullanılması nedeniyle özellikle eski ve tarihi şehir dokusunda ortaya çıkmaktadır. Modern bina örneği ise kentin çağdaş ve uygar yüzünü yansıtan Ataşehir'den seçilmiştir. Güvenli sınır mesafelerini elde etmek üzere örnek binalar için hesaplamalar yapılmış ve tablo halindeki uygulama sonuçları karşılaştırılmıştır. Sonuç olarak mevcut bina mesafeleri incelenen eski binalar için ışınımla oluşacak yangın tehlikesine karşı yeterli olmadığı halde incelenen modern bina için yeterlidir. Özellikle yanıcı malzemeden yapılmış ve birbirine oldukça yakın yerleştirilmiş tarihi binaların ışınımla oluşan yangın tehlikesine ve yangının diğer yayılma biçimlerine karşı koruyucu önlemler alınmalıdır.