

**V.A. ATANESYAN**

Yerevan State University of Architecture and Construction, Armenia

## **RESEARCH ON MONOLITHIC EXTERNAL WALLS INSTALLED IN PANEL FORMS WITH SIMULTANEOUS FACING**

The given work represents the research on external monolithic walls installed in vertical position with simultaneous implementation of facing works. Along with research of light concrete structure and properties for monolithic construction, joint work of concrete monolithic walls facing, installed in panel forms, was examined.

The research includes the joint work of facing with various stones with monolithic wall concrete. It also determines wall bearing ability. Wall fragments with facing samples were tested for axial compression. The work comprises test results of 12 wall fragments in the size of 100 x 45 x 30 cm, faced with tuff, basalt or travertine plates, and the chart of fragment deformation. The offered methods of simultaneous facing of external monolithic walls have technological and constructive advantages over the traditional method of subsequent facing.

**Keywords:** external monolithic walls, simultaneous implementation of facing, axial compression, deformation

Considering the combination of technology, economic and architectural requirements related to local conditions and perspective in quality for monolithic construction in Armenia, the following furnishing types in the concrete process are defined:

- Use of relief-formation matrixes, considered to be economically optimal option;
- Application of finishing plates of natural stone, providing the highest esthetic furnishing quality.

Large-scale researches on construction technology of monolithic light concrete external wall panels with simultaneous facing and relief furnishing were carried out in laboratories of YSUAC constructions and building materials technology.

Along with laboratory research of light concrete structure and properties for monolithic construction, joint work of concrete monolithic walls and facing, installed in panel forms, was examined.

It should be mentioned that earlier studies were conducted in the following spheres: compression durability and bending strength of large tuff blocks faced with tuff plates [1]; durability of plates coupling with limestone concrete body of blocks [2]; durability of wall panels fragments faced with tuff plates at axial compression

[3]. These researches were carried out for prefabricated construction therefore they are not applicable in technologically different monolithic construction.

The given work represents the research of monolithic external walls installed in vertical position with simultaneous implementation of facing works. The purpose of construction of such walls is the increase of monolithic buildings', durability, esthetic quality, technical and economic efficiency, as well as mechanization of laborious finishing works. One of the major tasks is ensuring joint work of facing with plates of various stones with concrete monolithic walls and determination of their bearing ability.

Tests for axial compression of 12 wall fragments in the size of  $100 \times 45 \times 30$  cm revetted with tuff, basalt or travertine plates in the size of  $30 \times 30 \times 2$  cm were carried out, in order to determine walls' durability and deformation properties. Wall fragments are manufactured in vertical position in a panel form of wooden design with a trellised external board, using flexible links for fixing the facing plates, under the copyright certificate No. 924314. When manufacturing wall fragments, the plates are installed in adjoining manner, and in four fragments revetted with basalt and travertine. Rubber laying is established between plates to be removed after dismantling of forms. Seams filled with solutions at  $2/3$  of depth are formed between plates. For manufacturing wall fragments faced with tuff plates there are used: concrete with strength at  $R_{com}$  compression = 8 MPas, density  $\gamma = 1335 \text{ kg/m}^3$  of the following composition (for  $1 \text{ m}^3$  concrete): slag sand of Armenian Karmrashen field - 334 kg; tuff sand of Agavnatun - 412 kg; slag rubble of Karmrashen - 274 kg; cement M400 - 274 kg; water - 306 l; rigidity of mix - 12-15 seconds, and macroporous concrete from Buzhakan pumice  $R_{com} = 11.8$  MPas, density -  $1175 \text{ kg/m}^3$ , of the following composition: sand - 500 kg, rubble - 170 kg, cement - 420 kg, "N200"+"DM"- $3,5 \div 2.4 \text{ kg/m}^3$ , water - 285 l, mobility 14-15 cm approximately. In other cases concrete  $R_{com} = 13$  MPas, density  $\gamma = 1356 \text{ kg/m}^3$  of the following composition is used: slag sand of the Karmrashen - 306 kg; tuff sand of the Agavnatun - 381 kg; slag rubble of Karmrashen - 282 kg; cement M400 - 337 kg; water - 295 l; rigidity of mix - 12-15 seconds, as well as concrete from finely porous Dzhraber lithoid pumice  $R_{com} = 22.6$  MPa, density -  $1470 \text{ kg/m}^3$ , of the following composition: sand - 550 kg, rubble - 550 kg, "N200" -  $2.5 \text{ kg/m}^3$ , water 240 l, cement - 270 kg, mobility - approximately 13 cm.

Filling of a panel form is made with consecutive layer-by-layer consolidation within 3 minutes, through deep vibrators. Samples are stored in laboratory conditions at temperature of 20 to  $25^\circ\text{C}$  and relative humidity of 60-70%. They are tested during a 28 days' period on compression, determining the deformation of facing and concrete layers on hydraulic press of 2 PG-500 capacity of 500 t within range of a dynamometer of 250 tons. A wall fragment sample at axial compression test is presented in Figure 1.

Loadings are made in steps, by means of pressing metal pillows on geometrical axis of sample's cross-section through laying in thickness of 1-1.5 cm. Each step

makes 0.1 R of concrete destruction. The endurance to 3 minutes is given at each step to take countings on devices. Longitudinal deformations are measured with two devices of hour type with the division price of 0.01 mm at base of 50 cm, one of which is installed on facing plates surface, and the second - on concrete surfaces. Cross-section deformations are measured with two devices with the division price of 0.001 mm at base of 20 cm, installed in the middle on two lateral faces at height of the tested sample. Deformation measurement is made to 0.9 R of destruction. If cracks appear, devices are withdrawn and samples led up to destruction.

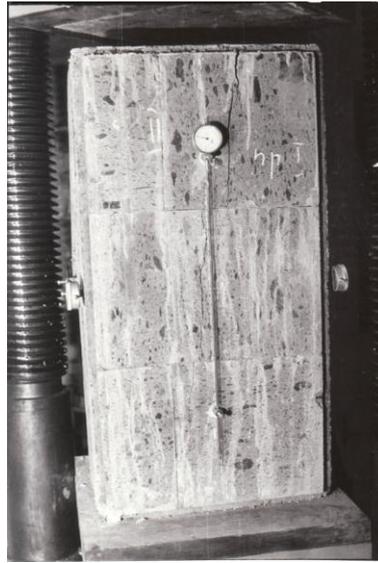


Fig. 1. Sample at axial compression test

The separation of plates from concrete was observed at compression layer when facing with basalt plates without solutions seams at  $\sigma_{com} = 0.79 R_{time}$ , with seams at  $\sigma_{com} = R_{time}$ , travertine without solutions seams at  $\sigma_{com} = 0.58 R_{times}$ , with seams  $\sigma_{com} = 0.9 R_{times}$ .

Sample test results are given in Table 1. The chart of dependence of compression, relative tension and relative longitudinal deformation is presented in the Figures 2 and 3.

Due to the joint work of tuff facing and concrete, sample durability at compression differs from concrete initial durability, which is not identical for samples faced with travertine and basalt plates without solution seams. In samples faced with tuff, cracks and destruction appear on concrete, instead of plates and concrete contact point (Fig. 2). It proves high durability of facing coupling. Thus, the deformations of plates and concrete are almost identical. The facing layer, working together with a concrete layer up to destruction, increases bearing ability of a sample. The work of a wall is likely to be considered as work of a two-layer device with various deforma-

tion modules. When calculating such device on axial compression, the facing is likely to be included in working section.

Similar conclusions are made by A.A. Shishkin [4] and S.N. Mekinyan [3] concerning the facing calculation in laying and wall panel durability. If facing and concrete coupling is reliable, the area of cross-section of monolithic walls faced with identical elasticity modules is bound to be taken into calculation.

Facing and concrete layer samples with basalt facing at axial compression show various deformation abilities (Fig. 3). The facing layer has the minimum deformation and works at an elastic stage up to separation of plates from concrete surface, whereas the concrete layer has the maximum deformation in elastic and plastic zone. Samples with travertine plates hold middle position for deformation properties (Fig. 3). Thus, when choosing facing material, it is necessary to consider also its elasticity module. Due to the huge difference of elasticity modules of a facing layer (when using plates of dense stones) and the main concrete layer, internal eccentricity is formed, and depending on wall element tension, facing plates can separate from concrete.

Table 1. Test results of walls fragments on axial compression

№	Concrete properties	Types of facing plates	Facing characteristics	Destruction force P time, H	Sample section area F cm <sup>2</sup>	Durability limit at compression R, MPas	
						Separately	Average
1.	Rcom = 8 MPas, $\gamma = 1335 \text{ kg/m}^3$	Artik tuff plates	Without solution seams	833340	1350	6.17	6.4
				902780		6.69	
2.	Rcom = 11.8 MPas, $\gamma = 1175 \text{ kg/m}^3$	Artik tuff plates	–    –	1417600	1350	10.5	10.15
				1323100		9.8	
3.	Rcom = 13 MPas, $\gamma = 1356 \text{ kg/m}^3$	Nurnuss basalt plates	With solution seams	944450	1350	6.99	7.1
			Without solution seams	986120 777780*		7.3	
4.	Rcom = 13 MPas, $\gamma = 1356 \text{ kg/m}^3$	Ararat travertine plates	With solution seams	1035720	1350	7.67	7.5
			Without solution seams	932148* 986120 569450*		7.3	
5.	Rcom = 22.6 MPas $\gamma = 1470 \text{ kg/m}^3$	Nurnuss basalt plates	With solution seams	1620150	1350	12	12.15
			Without solution seams	1660580 1311858*		12.3	
6.	Rcom = 22.6 MPas $\gamma = 1470 \text{ kg/m}^3$	Ararat travertine	With solution seams	1606550	1350	11.9	12.1
				1445895*			

		plates	Without solution seams	1687570		12.3	
				978791*			

The coupling mechanism of tuff plates and the factors influencing its high durability are as follows: due to vibro-consolidation of concrete mix, the released cement milk with the smallest sand particles are gathered on plate surface. Water absorption of plates and vibrating forces bring to knitting and sand particles stick firmly to plate surface and partially get into its pores, forming points of reliable connection.

Adhesive forces between superficial stone particles and a liquid phase of cement milk at cementation, promote durability increase of plates and concrete coupling. Thus the contact surface is a gear, providing high durability of concrete and facing coupling. Thin compensatory seams between plates got by means of flexible connections, play an essential role for durability of plates coupling. Facing plates and their strong connection with concrete could be damaged without these seams, due to various technologically shrinkable and temperature deformations of wall body and facing.

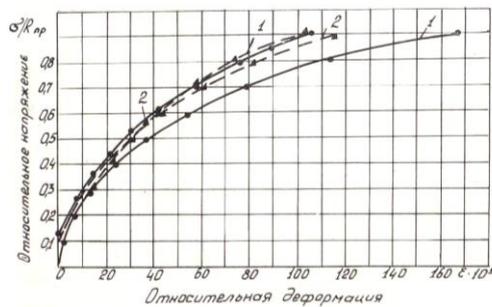


Fig. 2. Chart of wall fragments deformation faced with tuff plates: — Artik tuff, — — Agavnatun tuff (1 - concrete side; 2 - faced side)

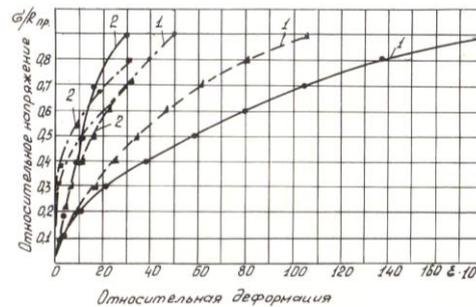


Fig. 3. Chart of wall fragments deformation faced with: — basalt plates; — — basalt plates with solution seams; — · — travertine plates (1 - the concrete side; 2 - faced side)

The rigidity of panel forms has an important influence on coupling durability. The pressed condition of facing plates with edges of a panel form’s external board, as well as the constrained conditions for concrete volume deformation in the course of consolidation, have favorable influence on durability of plates coupling. The above mentioned factors provide high durability of facing and concrete coupling, in construction of monolithic walls with simultaneous facing, and therefore, their joint work. The major factors, providing high coupling durability with solution, such as vibration, pressed condition of plates etc, are lacking in the widespread traditional method of walls subsequent facing. If we also consider the increased shrinkable deformations of a solution layer in comparison with a concrete layer, we may say they are the reason for plates separation at the traditional facing method.

Thus, the research revealed technological and constructive advantages of simultaneous facing of monolithic external walls as compared with traditional method of subsequent facing.

## CONCLUSIONS

The research on durability and deformation of external walls fragments, installed in a panel form with simultaneous facing with stone plates at axial compression, established the following:

1. Plates from porous stones, possessing high durability of coupling with bearing concrete, work together up to destruction and increase wall bearing ability.
2. Plates from dense stones increase wall bearing ability if high durability of concrete coupling is ensured.
3. Relative deformations of concrete and facing layer of porous stones are almost identical, whereas it differs strongly for dense stones. It can lead to the separation of plates from concrete layer surface at a certain tension in the wall. Solution seams are recommended to be left between plates, in order to prevent such phenomenon. The lack of them brings to the plates' separation from dense stones at tension 0.58-0.79 up to destroying.
4. Destruction of a facing layer of dense stones with solution seams is observed at the compressing loadings close to the destroying.
5. Joint work of facing tuff plates with wall concrete up to destruction is conditioned by smaller elasticity module, enabling to include the facing section as well as the wall section in the calculations.

## REFERENCES

- [1] Stepanyan V.A., Seismic Stability of Natural Stone Large-blocks. Construction in Seismic Countries, M: State Stroyizdat, 1957.
- [2] Arakelyan A.A., Light Concrete Large Blocks and Vibrating Method of Laying Construction, Yerevan 1958.
- [3] Mekinyan S.N., Research on Durability of External Wall Panel Fragments Faced with Tuff Plates at Central Compression, Research on Stone Constructions, AISM, Yerevan 1964.
- [4] Shishkin A.A., Influence of Facing Coupling Ways on Bricklaying Durability, M.: 1936.

## BADANIA MONOLITYCZNYCH ŚCIAN ZEWNĘTRZNYCH Z RÓŻNYMI TYPAMI OKŁADZIN

**W pracy przedstawiono badania ścian monolitycznych przy zastosowaniu różnego rodzaju okładzin, zainstalowanych w formach. Praca zawiera wyniki testu dla 12 fragmentów ścian wielkości 100 x 45 x 30 cm oraz wykresy odkształceń. Zapropono-**

---

**wane metody wykonania okładziny zewnętrznych ścian monolitycznych mają technologiczną i konstrukcyjną przewagę nad tradycyjnymi rozwiązaniami okładzin.**

**Słowa kluczowe: ściany monolityczne, okładziny ściennie, odkształcenia, wytrzymałość na ściskanie**